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MONTHLY NOTICES

OF THE

L.7682.

ROYAL ASTRONOMICAL SOCIETY,

CONTAINING

PAPERS, ABSTRACTS OF PAPERS, AND

REPORTS OF THE PROCEEDINGS

OF THE SOCIETY

FROM NOVEMBER 1890 *TO NOVEMBER* 1891.

VOL. LI.

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LI. NOVEMBER 14, 1890. No. 1

Lieut.-General J. F. TENNANT, C.I.E., R.E., F.R.S., President, in the Chair.

Robert Isaac Finnemore, J.P., F.R.Hist.Soc., Durban, Natal;
William Friese-Greene, 92 Piccadilly, W.;
George Higgs, 467 West Derby Road, Liverpool;
Neville Holden, High Street, Lancaster; and
Harold Jacoby, B.A., Columbia College Observatory, New York,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Bhuban Mokan Bandyopadhyay, B.A., F.R.Hist.Soc., Professor of Science and Lecturer on Astronomy at the Christian College, Lucknow (proposed by Captain S. G. Burrard);
John Billington Booth, J.P., Preston, Lancashire (proposed by Dr. R. Copeland);
Joseph Brooks, Trigonometrical Survey of New South Wales, Lands Department, Sydney, N.S. Wales (proposed by R. L. J. Ellery);
James S. Browne, Lamp Manufacturer, 170 Sloane Street, S.W. (proposed by the Rev. T. Mackereth);
Edward Tremlett Carter, Assoc. Inst. E.E., School of Electrical Engineering, 12 Princes Street, Hanover Square, W. (proposed by Andrew C. D. Crommelin);
Rev. A. L. Cortie, S.J., St. Beuno's College, St. Asaph, North Wales (proposed by W. H. M. Christie);

William Bladen Croft, M.A., Physics Master of Winchester College, 9 College Street, Winchester (proposed by Professor C. Pritchard);

James Gallaher, The Limes, Leyton, and St. George's House, Eastcheap, E.C. (proposed by James Glaisher);

Rev. H. Grattan Guinness, D.D., F.R.Hist.Soc., F.R.G.S., Harley House, Bow, and Cliff House, Curbar, Derbyshire (proposed by E. Walter Maunder);

C. W. H. Jeavons, Analyst, Horseley Place, Tipton, Staffordshire (proposed by A. Taylor);

John Mitchell, Brockholes, Huddersfield (proposed by Joseph Gledhill);

William M. Pierson, San Francisco, California, U.S.A. (proposed by Edward E. Barnard);

James Lidderdale Scott, Shanghai, China (proposed by L. S. Little);

Arthur Laidlaw Selby, M.A., Assistant Professor of Physics in the University College of South Wales and Monmouthshire, Cardiff (proposed by Professor R. B. Clifton);

Rev. Walter Sidgreaves, S.J., Director of the Observatory, and Professor of Physics, Stonyhurst College, Blackburn, Lancashire (proposed by W. H. M. Christie);

John Peter George Smith, Sweyney Cliff, Coalport, Shropshire (proposed by Sir William Thomson);

Arthur J. Walker, New College, Oxford (proposed by Professor C. Pritchard).

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155 presents were announced as having been received since the last meeting, including, among others:—

Birmingham (J.), The Red Stars, new edition by Rev. T. E. Espin, presented by Rev. T. E. Espin.

Catalog der Astronomischen Gesellschaft, Zone + 55° bis + 65°, Zone + 1° bis + 5°, presented by the Society.

Cayley (A.), Collected Mathematical Papers, vol. 3, presented by the Author.

Clerke (A. M.), The System of the Stars, presented by the Author.

Engelhardt (B. d'), Observations Astronomiques faites . . . dans son Observatoire à Dresde, IIme. partie, presented by the Author.

Opere de Galileo Galilei, Edizione Nazionale, vol. 1, presented by the Italian Government.

Schubert (E.), Tables of Melpomene and Eunomia, presented by the American Nautical Almanac Office.

Tisserand (F.), Traité de Mécanique Céleste, tome 2, presented by the Author.

Winterhalter (A. G.), The International Astrophotographic Congress, and visit to European Observatories, &c., presented by the U.S. Naval Observatory.

Ahmed Mukhtar Pasha, The Reform of the Calendar, translated by Sir J. W. Redhouse, K.C.M.G., presented by Sir J. W. Redhouse.

Photographs of the Moon taken with the Great Equatoreal of the Lick Observatory (3 original negatives and one glass positive). Photograph of the Total Solar Eclipse, 1889, Dec. 22, by J. M. Schaeberle (2 glass positives). Photograph of *Jupiter*, taken with the Great Equatoreal of the Lick Observatory, by E. S. Holden (glass positive — enlargement). Comparative photographs of the high Sun and low Sun spectra, presented by Mr. F. McClean. } Presented by the Lick Observatory.

On the Real and Apparent Variations of the Latitude of Greenwich.

By Professor F. Folie.

(*Communicated by the Astronomer Royal.*)

The real variations of latitude are, we know, given by the formula

$$r \cos (int + \beta).$$

The values of r given by Peters and Downing * are

$$0''{\cdot}079 \text{ and } 0''{\cdot}075.$$

The same value, determined by me from the diurnal variations in R.A., deduced from the observations of W. Struve at Dorpat in 1823–25, is:

1823	...	...	$0''{\cdot}080$
1824	...	...	$0''{\cdot}075$
1825	...	...	$0''{\cdot}086$

The value of the constant β, determined by Peters, Nyrén, and Downing,† are, the last being brought back to Dorpat:

1842	...	...	$341^\circ{\cdot}6$
1850	...	...	224
1872	...	...	175

Astronomers have not yet been able to bring these values into accordance by assuming the adopted increase of 430° (about) yearly, corresponding to a period of 305 days.

Theoretical reasons, agreeing with my ideas as to the constitution of the central nucleus of the Earth, have made me doubt the

* I cannot use those of Nyrén, because they are too discordant.

† Peters (*A. N.*, xxii., 1845, 128). Nyrén (*St. Pétersbourg M* 1873, no. 10, pp. 37, 38). Downing (*M. N.*, xl., 1880, pp. 431, 432).

accuracy of this period,* and I have tried to deduce it from the observations, after having found from those of W. Struve (cited above) that the value of 430° is considerably too large. Here are the values deduced from the observations, at April 1 of each of the three years:

1823	...	...	236° 43′	Mean 246°.
1824	...	...	247 23	
1825	...	...	254 6	

A series of observations by Preuss has given me for April 1, 1838, 310°. The difference, 310 − 246 = 64° divided by 1838 − 1824 = 14 gives only 4°·5, or an increase of 364°·5 yearly, which is too small. I divide 360° + 64° = 426° by 14, which gives 30°·5 nearly, and 390°·5 for the annual increase.

Applying this to the observations, I find

			Residuals.
1824·0	151°	W. Struve	...
1838·0	151° + 14 × 30°·5 = 218°	Preuss, 221°	−3°
1842·0	151° + 18 × 30°·5 = 340°	Peters, 341°·6	−1°·6
1850·0	151° + 26 × 30°·5 = 224°	Nyrén, 224°	0
1872·0	151° + 48 × 30°·5 = 175°	Downing, 175° †	0

If I take 340° for 1842, or 224° for 1850, the same annual increase will naturally give no residuals for 1850 and 1872, or for 1872.

There is no doubt, then, that the constants determined by astronomers are in as great accordance as we can desire with the annual increase of 390°·5, corresponding to a period of 336·7 days instead of 305 days, the value which has hitherto been assumed. This last number is deduced from the value 0·00327 ascribed to $\frac{C-A}{A}$. This value is exact for the Earth considered as a whole solid body. The real value being smaller, 0·00296, we must admit in conclusion that we cannot consider the Earth as a solid body in the studies of variations of latitudes.

We can, from the above, assume with confidence, for the variations of latitude of Greenwich, the formula:

$$r \cos (205° + 390°{\cdot}5\, t),$$

in which t = number of years from 1872·0 and r = 0″·078, the mean of the values of Peters, Downing and Folie.

These are the results for the real variations of latitude, or the distance between the instantaneous pole and the geographical pole of the Earth. But the constant r is also, with a very slight

* See *Annuaire de l'Observatoire Royal de Bruxelles*, pour 1890, p. 299.

† Value referred to Dorpat.

difference, the constant of the *initial nutation* of the geographical pole, determined in obliquity and in longitude by the formula:

$$\Delta\theta = -r\sin[(1+i)\,nt+\beta]$$
$$\sin\theta\,\Delta\lambda = -r\cos[(1+i)\,nt+\beta],$$

whence we may deduce, as we know, $\Delta\alpha$ and $\Delta\delta$.

The apparent places of stars are, then, subject to variations of a period almost exactly diurnal, since $i = \frac{1}{336{\cdot}7}$ nearly, and no determination of latitude can be exact if not corrected for these variations. And Laplace is right in saying: "Si la valeur de r était sensible, on le reconnaîtrait par les variations journalières de la latitude," * recognising, in fact, the correction to be applied to the latitude of Greenwich, deduced from two true consecutive zenithal distances of *Polaris*, at upper and lower transits.

If δ be the *true* declination of the star, as it is *calculated by the astronomers*, $\Delta_1\delta$ the initial nutation in declination, the true *real* declination will be $\delta+\Delta_1\delta$, and we shall have for the upper transit [z=true real zenithal distance, ϕ=colatitude].

$$z = \phi - \delta - \Delta_1\delta.$$

But we see immediately that after twelve sidereal hours the sign of $\Delta_1\delta$ must change and maintain almost the same value. We have, then, for the lower transit

$$z' = \phi + \delta - \Delta_1\delta.$$

From the two equations we deduce

$$\phi = \frac{z+z'}{2} + \Delta_1\delta$$

instead of

$$\phi = \frac{z+z'}{2}$$

the value given by astronomers.

This correction is by no means to be neglected, if we admit the coefficient $0''{\cdot}078$. It is for Greenwich

$$i = \frac{1}{336{\cdot}7} \text{ or } int = 390^\circ{\cdot}5 \text{ yearly};$$
$$t = \text{sidereal days from } 1872{\cdot}0;$$
$$nt = 360^\circ \text{ for a sidereal day};$$
$$\beta = 205^\circ;$$
$$\Delta_1\delta = \sin\alpha\,\Delta_1\theta + \cos\alpha\sin\theta\,\Delta_1\lambda$$
$$= -r\cos\{(1+i)\,nt+\beta-\alpha\},$$

which expression will change its sign after twelve hours, if we neglect the half degree for the increase of it, and the colatitude

* *Mécanique Céleste*, livre v., art. 4.

deduced from each pair of observations must be corrected by this quantity, as I have said above. Is it necessary to add that if we will take the hundredth of a second of arc in account, it is quite indispensable to correct the observations for initial nutation?

The expression in R.A. of the initial nutation is:

$$\Delta\alpha = (\cot\theta + \sin\alpha\tan\delta)\sin\theta\Delta_i\lambda - \cos\alpha\tan\delta\Delta_i\theta$$
$$= -r\{M\cos[(1+i)t+\beta] + N\sin[(1+i)t+\beta]\}.$$

M and N being respectively $\cot\theta + \sin\alpha\tan\delta$ and $\cos\alpha\tan\delta$.

If r has the value given by the determinations of Peters, Downing and myself, this correction may attain to $0^s{\cdot}2$ of time for *Polaris*. But I think this value of r to be still doubtful, in spite of the accordance of those three determinations.

A very important consequence which arises in taking no account of the variations of latitude as also of the initial nutation, is its influence on the determination of the obliquity of the ecliptic.

If E_o = mean obliquity determined as usual, the true expression for it, at the summer solstice, is

$$E_m = E_o + \gamma\cos(int+\beta) + \gamma\sin[(1+i)nt+\beta],$$

the first term of the corrections arising from the variation of latitude, the second from the initial nutation.

At the winter solstice, this expression becomes

$$E'_m = E'_o + \gamma\cos(int'+\beta) - \gamma\sin[(1+i)nt'+\beta];$$

the sign of the correction of the initial nutation is changed because, at the solstices, when the Sun's right ascension is 90° or 270°, the initial nutations in declination,

$$\Delta_i\delta = \sin\alpha\Delta_i\theta,$$

are equal and opposite in sign.

But, at the winter solstice, t is increased by an entire number j of sidereal days, taken as unity, and twelve hours more, so that

$$t' = t + j + 12^h$$

and

$$E'_m = E'_o + \gamma\cos(int'+\beta) + \gamma\sin(j + nt + int' + \beta)$$
$$= E'_o + \gamma\cos(int'+\beta) + \gamma\sin(nt + int + \beta),$$

because j is a multiple of 360°.

The correction of obliquity at the summer solstice $E_m - E_o$ will be:

$$\Delta E = 2\gamma\cos\left(\frac{nt}{2} - 45°\right)\sin\left(\frac{nt}{2} + 45° + int + \beta\right)$$

and at the winter solstice

$$\Delta E' = 2\gamma\cos\left(\frac{nt}{2} - 45°\right)\sin\left(\frac{nt}{2} + 45° + int' + \beta\right).$$

These two corrections are not equal; the difference $\Delta E - \Delta E'$ will be:

$$\Delta^2 E = -4\gamma \cos\left(\frac{nt}{2} - 45^\circ\right) \sin in \frac{t'-t}{2} \cos\left(\frac{nt}{2} + 45^\circ + in\frac{t'+t}{2} + \beta\right)$$

as $t'-t$ is a half year,

$$in\frac{t'-t}{2}$$

will be equal to

$$\frac{390^\circ{\cdot}5}{4} = 97^\circ{\cdot}6; \text{ its sin} = 0{\cdot}9915,$$

and we have then

$$\Delta^2 E = -3{\cdot}966\gamma \cos\left(\frac{nt}{2} - 45^\circ\right) \cos\left(\frac{nt}{2} + 45^\circ + in\frac{t+t'}{2} + \beta\right),$$

or, if we write

$$in\frac{t'+t}{2} = int + 97^\circ{\cdot}6,$$

and

$$\beta + 7^\circ{\cdot}6 = \beta'$$

$$\Delta^2 E = 3{\cdot}996\gamma \cos\left(\frac{nt}{2} - 45^\circ\right) \sin\left(\frac{nt}{2} + 45^\circ + int + \beta'\right).$$

We will apply the formula to the determination of obliquity for Greenwich 1872, and take for the equinox

$$\beta = 205^\circ + 0{\cdot}2163 \times 390^\circ{\cdot}5 = 289^\circ{\cdot}5;$$

$$\beta' = \beta + 7^\circ{\cdot}6 = 297^\circ{\cdot}0;$$

and

$$3{\cdot}996\gamma = 0''{\cdot}3.$$

From the equinox to the solstice t is increased by an entire number of days + 6 hours. So that $\frac{nt}{2}$ will be $= 45^\circ$.

The expression of $\Delta^2 E$ will then be

$$\Delta^2 E = 0''{\cdot}3 \cos(int + \beta') = 0''{\cdot}3 \cos(97^\circ{\cdot}5 + 297^\circ)$$
$$= 0''{\cdot}3 \cos 34^\circ{\cdot}5 = 0''{\cdot}25.$$

Such is the difference existing between the obliquity determined at summer and at winter solstices in 1872, at Greenwich, if we admit as exact the determination of the initial nutation made by Downing.

Moreover, if my period of 336·7 mean days is admitted as exact by astronomers, instead of the period of 305 days, adopted until now, and the great accordance between all the determinations compels this admission, it is certain, as I have said, that we cannot consider the Earth as a solid body, for which $\frac{C-A}{A}$ oscillates, at the most, between 0·00324 and 0·00328 (taking into

account the exactness of the constants of precession and nutation), and, in consequence, the period between 304 and 306 days.

And if we cannot consider the Earth a solid body, the diurnal nutation, of which the period is half a sidereal day, certainly exists.

I estimate its coefficient to be twice as great as that of the initial nutation. It is, then, a new correction to be applied to the observations, if we will be sure of the hundredth of a second of arc.

And then, can we even be sure ?

Brussels: July 5, 1890.

Preliminary Note on the Duplicity of α Lyræ.

By A. Fowler.

(*Communicated by Professor J. Norman Lockyer, F.R.S.*)

A photographic study of stellar spectra has recently been commenced at Kensington, under the direction of Professor Lockyer, and one of the first results is the discovery that *α Lyræ* is a binary of the *β Aurigæ* and *ζ Ursæ Majoris* type. The principles of the method have already been fully stated by Professor Pickering (*Monthly Notices*, vol. L, p. 296), but it may be remarked that the evidence of duplicity depends upon the fact that when both components are travelling in opposite directions in the line of sight, the lines of the spectrum which are common will appear double, the spectrum of one being displaced towards the red and the other towards the violet. When the components are moving at right angles to the line of sight, the lines will be single. During a whole period, therefore, a given line will first appear single, let us say, then it will gradually double until a maximum is reached; it will then narrow and become single, widen to another maximum and again appear single.

In the spectrum of *α Lyræ* the principal lines are those of hydrogen, but these do not show the duplication because the separation is not greater than the thickness of the lines. A variation in width, however, amounting almost to doubling in the more refrangible lines, is very obvious. Next to the hydrogen lines the K line is strongest, and this is sufficiently fine and distinct to render the detection of duplication quite easy. The remaining lines are very faint and their duplication is not very apparent. They are only seen to be double in two or three photographs. Fourteen photographs have already been obtained, dating from October 3 to November 4, but, owing to unfavourable weather, there are long breaks in the series. There are sufficient data, however, to enable a provisional period of revolution and the probable form of the orbit to be determined.

The following table summarises the results so far obtained, the second column giving the separation of the K lines in tenth-metres, and the third the corresponding relative velocity of the two components in the line of sight:—

Date.	Separation of K Lines.	Relative Velocity in the Line of Sight.
Oct. 3, 9 P.M.	3·8	180 miles per second
„ 8, 8 „	7·8	370 „ „
„ 9, 7 „	4·9	232 „ „
„ 10, 7.20 P.M.	5·5	260 „ „
„ 11, 8.30 „	4·6	218 „ „
„ 12, 8.15 „	6·2	294 „ „
„ 14, 10 „	5·5	260 „ „
„ 17, 10 „	0·0	
„ 27, 8 „	2·3	109 „ „
„ 28, 6.30 „	0·0	
Nov. 1, 8 „	0·0	
„ 1, 8.30 „	2·3	109 „ „
„ 1, 10 „	3·8	180 „ „
„ 4, 9 „	0·0	

A discussion of these data shows that they are all fairly well satisfied by assuming a circular orbit, the plane of which almost passes through the Sun, with a period of revolution of about 24·68 hours. This is best seen when the results are plotted graphically, the variations being represented by the curve of sines. In the accompanying diagram the curve represents the variations in the distance between the K lines assuming the orbit and period to be as stated, and the dots show the actual results deduced from the photographs, the maximum separation being taken as 10 units. It will be seen that practically every dot falls in its proper place on the curve, the slight discrepancies being within the limits of error in measurement.

In the case of ζ *Ursæ Majoris* Professor Pickering found a period of about 52 days, with a maximum relative velocity of 100 miles per second, and for β *Aurigæ* a period of four days with a maximum velocity of about 150 miles per second. Vogel has further discovered by the photographic method that *Spica* is accompanied by a dim companion which completes a revolution in about 4 days, the diameter of the orbit being 6 millions of miles, and the orbital velocity about 50 miles per second. In the case of α *Lyræ*, as already stated, I have found the period to be probably about 24·68 hours, and the maximum relative velocity about 370 miles per second. This period is remarkably short, but it does not seem inconsistent with the great velocity indicated by the photograph of October 8, and is partially confirmed by

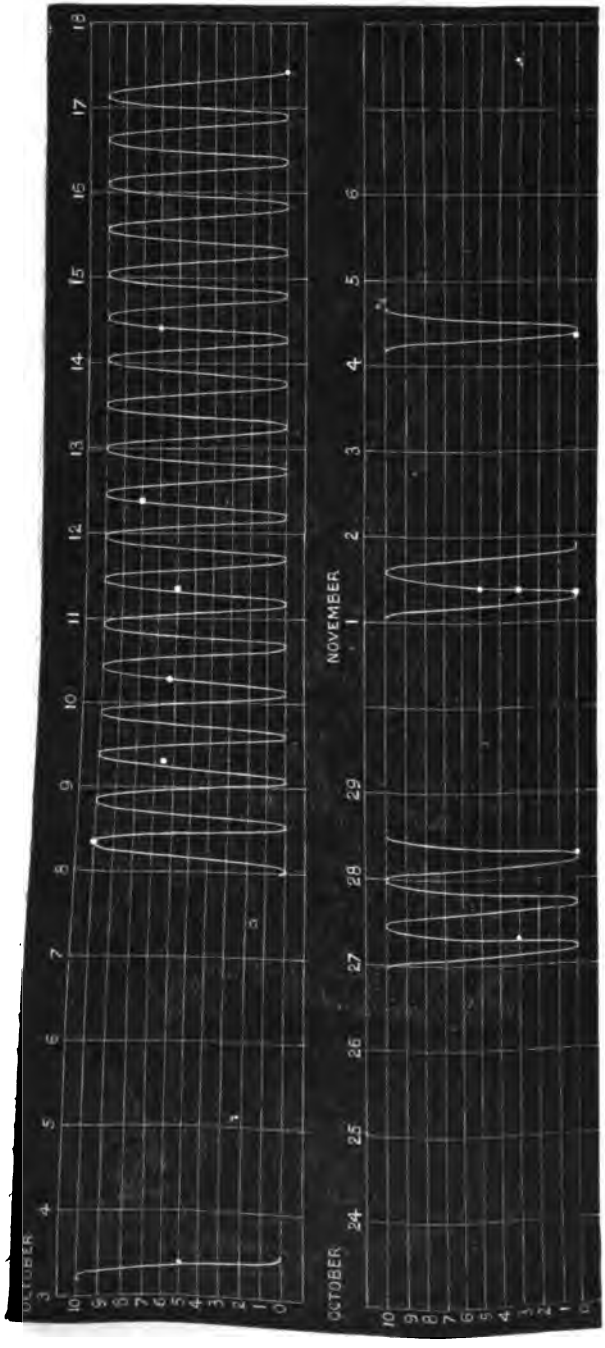

Diagram showing the variations in the separation of the K lines in the spectrum of *a Lyræ*.
(The maximum separation is taken as 10 units.)

the three photographs of November 1, taken at short intervals. The doubling of the line takes place so quickly that it is difficult to say when it is absolutely single, and hence the minima recorded in the table are only approximate.

It seems fair to assume that 370 miles per second is about the maximum relative orbital velocity, and this gives a little over five millions of miles as the distance between the components. The total mass will therefore be about 22½ times that of the Sun, and as there is no appreciable difference in the intensity of the K lines, or of the hydrogen lines as far as can be estimated from their partial separation, the masses of the components are probably about equal. These values will, of course, require modification if the plane of the orbit does not pass through the Sun. They must not yet be regarded as final, in consequence of the absence of a series of photographs taken at short intervals. Such a series will be obtained as soon as possible; they were not taken in the first instance because it was not suspected that the period was so short. Unfavourable weather has since prevented this being done, and I have taken this opportunity of bringing my results before the Society in the hope that some other observer with better atmospheric conditions may be induced to take up the question.

The mean value of the parallax of *α Lyræ*, as determined by the Struves, Peters, and others is 0″·16, and if we take this as correct, the angular distance between the components at the elongations would be 0″·008. If Elkin's value (0″·034 ± 0·045) be taken, the angle will be very much less, and it is not likely, therefore, that the components will ever be separated by a telescope.

The instrument employed in the investigation was the 10-inch refractor belonging to the Royal College of Science, with two prisms of 7½° each in front of the object-glass. The length of the spectrum from F to K is about an inch and a half, and the maximum separation of the K lines in *α Lyræ* $\frac{1}{5}\frac{1}{0}$th of an inch, or 35″. The exposure was generally a quarter of an hour.

I have to express my obligation to Messrs. Rogers and Baxandall for assistance in taking the photographs.

Royal College of Science,
South Kensington.

On the Variation of the Spectra of R Coronæ and R Scuti, and on the Spectra of R Aurigæ and R Andromedæ. By the Rev. T. E. Espin, B.A.

R Coronæ.—The observations of this star show a curious change of spectrum. Throughout the observations the star was examined on each night with different spectroscopes, and, beginning with feeble dispersion, the examination was continued till the highest dispersion the star would bear was reached.

The spectroscope was very carefully focussed on the strong F line in *a Coronæ*. I give the results of the observations in detail:—

1890, *March* 26.—Very clear; moonlight. Star about 5·8 mag. Colour, yellowish white. Nothing certain seen; sometimes irregularities, either dark or bright lines suspected.

1890, *April* 10.—Continuous spectrum, but again suspected lines, one bright one strongly suspected near the place of F, but believed more refrangible.

1890, *September* 8.—A most wonderful change has taken place in this star's spectrum. Two large absorption bands have appeared, one in the bluish-green, and one in the bluish-violet. These bands are sharply defined on the least refrangible side. Bringing the spectrum to a line, bright patches were seen far away in the violet—these may be bright lines or bright spaces. The star is now pale yellow. The magnitude still about 6.

1890, *September* 14.—The spectrum is apparently of the IV. type, since the bands fade away on the more refrangible side, but are sharply defined on the less refrangible. The band in the bluish-green was thought to be occasionally resolved into fine lines; between the two bands a bright line was suspected. The star is of the same magnitude and now pale orange.

1890, *October* 8.—Heavy mist, eventually putting a stop to telescopic work. The star is only dim, but the bands seem to have faded.

1890, *October* 10.—The star has now nearly returned to the continuous first type spectrum observed in the spring. The big band in the bluish-green has disappeared, but the band in the violet is probably there still, but faint. The bright line previously mentioned again suspected. The star is now yellowish-white, and the magnitude about the same.

R Scuti: 1890, *August* 21. *III. Type.*—The bands are faint. Bands 1, 2, 3, of Dunér's nomenclature, seen, and also 7 and 8, which are the strongest.

1890, *August* 23.—Estimated 7·2; pale orange-red; carefully examined. The spectroscope each time focussed on λ *Aquilæ*. Type III., but peculiar. The usual bands, 1, 2, 3, seen, the bands 4 and 5 faint, 7 and 8 are strong. Bringing the spectrum to a line, bright knots seen in the violet and ultra-violet, either lines or spaces.

1890, *September* 8.—The bands 4 and 5 are much better seen to-night, but the other bands remain the same. The star is now brighter.

1890, *October* 10.—The star is now about 6 mag. The III. type spectrum is no longer certainly seen. A remnant of band 7 still remains; the others have almost, if not quite, disappeared. Perhaps 8 is there.

1890, *October* 12.—The star about 6 mag. Star low, tremulous, and type doubtful. Possibly III., but very indistinct.

1890, *October* 15.—The star is about 6·5. The spectrum is again clearly III. type. Bands 7 and 8 best seen, also 1 to 4

visible. The bands are, however, faint and dim, but are larger now, and the spectrum is similar to that observed on August 21.

1890, *November* 1.—Normal III. type, and about 6·8 mag. The bands are well seen in all parts of the spectrum. Bands 7 and 8 are especially broad.

R Aurigæ: 1890, *August* 18.—Mag. 7·2; colour fine rose-red. Very fine III. type, and the spectrum appears to resemble that of *Mira* rather than *R Andromedæ*.

R Andromedæ: 1890, *August* 23.—Magnitude 7·3 ±. Bands not deep, except in the blue and violet. Bringing the spectrum to a line, several bright lines in the violet and ultra-violet suspected. F possibly bright, but not sure about this.

1890, *September* 8.—The star has increased in light, and γ *Hydrogen* and F certainly seen, but still faint.

1890, *September* 14.—Bands in the red well seen, the yellow bands faint. F very plain now.

1890, *September* 15.—The F line now a wonderful spectacle. The star is not so red, the bands are generally faint except in the red. A bright space in the yellow looks like a mass of fine bright lines. A deep band in the violet. Hγ and D_3 possibly bright.

Comparative Photographs of the High Sun and Low Sun Visible Spectra, with Notes on the Method of Photographing the Red End of the Spectrum. By Frank McClean, M.A.

The accompanying photographs represent the High Sun and the Low Sun visible spectra from (H) to (A). The High Sun spectrum has been taken, as far as possible, when the Sun's altitude was over 45°, and the Low Sun spectrum when it was under 7½°. The depth of atmosphere traversed for the Low Sun spectrum was thus about five times that traversed for the High Sun spectrum. A few exceptions to this rule are indicated in the accompanying Table. The elastic force of aqueous vapour in the atmosphere when each photograph was taken is given in the same Table.

The photographs are in sections numbered from I. to XIII. From I. to XI. they correspond to the divisions of Ångström's chart. The scale is also about the same, but in the photographs it varies as the secant of the angle through which the grating is turned from its central position. There is a slight break in the scale between Sections IV. and V., owing to a different object-glass being employed for the violet portion of the spectrum.

The corresponding sections of the High Sun and Low Sun spectra are mounted in juxtaposition, so as to show by comparison the atmospheric groups of lines. These groups divide themselves, on inspection, into two classes. Firstly, those in which the bulk of the lines grow uniformly darker as the Sun

approaches the horizon. Secondly, those in which many of the lines become exceptionally prominent under the same circumstances, and especially when there is much moisture in the air.

To the first class belong the groups (A) (a) and (B). To the second class belong the group about (C) and (β) above it, the group called (a) by Ångström, or (C_6) by Brewster and Gladstone; the rain-band group below and about (D), and the group (δ) above (D). Also two small groups called (ς) and (ι) by Brewster and Gladstone, situated near wave-lengths 5430 and 5040. The remaining bands indicated by Brewster and Gladstone are not easily distinguishable. Indications of groups of fine atmospheric lines exist in the region of (H), but this appearance may partly be caused by the weakness of the Low Sun spectrum. Weakness in the light of the spectrum affects the photographs in much the same way as strength in the lines. In some of the groups, the fainter solar lines appear weaker in the Low Sun spectrum than in the High Sun. This indicates that the stronger lines are also shown less strong than they should be, in the Low Sun spectrum.

The moderate scale of the photographs has some advantages. The photographs thus represent the well-known features of the solar spectrum in the compact form in which they are familiar. They constitute a companion to Ångström's chart, and can be directly compared with any part of it, and the lines due to the various substances identified from it. Also corresponding photographs of the metallic spectra can be obtained by means of the induction spark, as is shown by the photographs of the iron and the iridium spectra, laid before the Society in May 1888. The main divisions of the scale of wave-lengths have been placed on the photographs from Ångström's chart. The photographs, however, are not suitable for determining any principal measurement. They are only suitable for the identification of groups of lines, and for filling in the details between standard lines, whose wave-lengths have been determined by direct observations with proper instruments.

The photographs are enlarged about $8\frac{1}{2}$ times from the original negative.

The following are a few particulars of the instruments and methods employed for obtaining the photographs, and more especially those of the red end of the spectrum.

The spectroscopic apparatus is that which the writer has made use of with little change since 1879, with a large Rutherfurd grating which he then obtained. During the present year he has substituted a Rowland plane grating for the Rutherfurd, and these photographs are taken with it.

A fixed heliostat, commanding a large extent of true horizon, reflects the solar light into a telescope fixed parallel to the polar axis. The object-glass of this telescope is 98 inches in focal length, and it is stopped down to 4 inches aperture. Near its

focus a right-angled prism reflects the solar image horizontally into the spectroscope.

The spectroscope consists of collimating and observing telescopes of 2 inches aperture each, and respectively of 50 and 36 inches focal lengths.* These are fixed at an inclination of 16° 30′ to one another, and at their intersection the grating rotates horizontally. The positions of the grating for the different sections of the spectrum are given in the Table appended. The dispersion is double the corresponding rotation.

There are two important points with respect to the method of obtaining the photographs of the spectrum. These are, the selection of the absorption screens, and the preparation of the plates.

In the present case, for the purposes of absorption, use is made of glass cells one-sixth of an inch thick. These are filled with suitably coloured solutions, and placed on a stand in front of the slit. The colour can be chosen, not only to exclude the overlapping spectra, but also, by its variable absorption, to equalise, to some extent, the variable actinic force of the section to be photographed.

Many different dyes answer the purpose, but the following scheme will be found simple and effective for photographing the 2nd order spectrum :—For Sections I. and II., no screen.

For Sections III. to VII., a solution of 1 part of esculin in 2,000 water, with a trace of carbonate of ammonia. For Sections VIII. to XIII., 1 part of aurine in 600 of water.

Some variations of these, however, are of advantage in order to equalise the actinic force. For Section III., 1 of sulphate of quinine in 400 water, with a trace of sulphuric acid. For Section IV., 1 of chloride of copper in 12 of water. For Sections VIII. and IX., 1 of aniline orange in 3,000 of water. Changes in strength may also be made.

In case the overlapping spectrum of the 3rd order has to be photographed, there may be used—For Sections VII. and VIII., 1 of methyl blue in 15,000 of water. For Sections IX. to XIII., 1 of chloride of copper in 3 of water.

Mawson and Swan's lantern and photo-mechanical plates have been found most suitable for the work, on account of their hardness and freedom from grain. They have been employed by the writer for the photography of the spectrum since 1887. For Sections I. and II. they are used as they are. For Sections III. to VI. they are prepared with erythrosine; and for Sections VII. to XIII. they are prepared with cyanin and ammonia.

The erythrosine plates present no difficulties. A bath is prepared of $2\frac{1}{2}$ ounces of water, and 6 minims of 1 erythrosine in 100 water. The plate is first placed in water for one minute, then in the erythrosine bath for one minute, and again in water for one minute. It is afterwards dried slowly in the drying-box.

* The alternative object-glass for use with the violet end of the spectrum is of 38 inches focal length.

The colour of the plate should be almost imperceptible, or otherwise the plate will fog in development.

The preparation of the cyanin plates is based on Schumann's formula as given in Vogel's Manual, published by Gauthier, 1887. A much larger proportion of alcohol is required to keep the plates free from specks of cyanin, a larger proportion of ammonia is necessary to make anything of the extreme red spectrum, and a smaller proportion of cyanin must be used to avoid overcolouring the plates.

For the preparation of the plates, baths are prepared as follows:—

No. 1. 1 oz. methylated alcohol.
35 minims of ammonia (full strength).
1½ ozs. of water.

No. 2. 1 oz. methylated alcohol.
8 minims solution of cyanin, 1 in 500 alcohol.
35 minims ammonia.
1½ ozs. water.

Both baths are brought to a temperature of about 65° Fahrenheit.

The plate is put in No. 1 for 45 seconds, then in No. 2 for 60 seconds, and again in No. 1 for 45 seconds. This treatment keeps the plate of an even colour. The colour of the plates must be almost imperceptible, or they will fog. The best developer is that recommended by the makers for the photo-mechanical plates, with, for the extreme red spectrum, an extra quantity of ammonia. Should the plates show a tendency to fog, a preliminary bath of weak preservative (metabisulphite of potash) for from 20 to 40 seconds is of marked advantage.

Samples of cyanin vary exceedingly. That used as above was obtained through Messrs. Griffin & Co. from a manufacturer in Dublin.

Cyanin plates deteriorate with keeping, especially along the margin. They are at their best for three or four days after preparation, but remain quite fit for use for a fortnight. A better result might be expected, if a good substitute for cyanin could be found that would work without ammonia.

On a bright day the exposures required in the way described are:—For Sections I. to VII., varying up to 2 minutes. For VIII. to XIII., varying from 2 to 20 minutes. For the Low Sun spectrum 2 or 3 times this exposure is necessary.

A set of negatives of the whole spectrum are placed before the meeting. They are not, however, the best negatives selected for enlargement.

Some idea of the minute detail attainable on the negatives may be gathered from an inspection of the negative of No. 1 section under the microscope. The field of view covers about one-eighth of an inch, and in that space over eighty well-defined lines in characteristic groups may be counted. Some of these

lines are spaced 1000 to the inch, and correspond to an angular dispersion of 5 seconds.

This negative, however, is taken on an unprepared plate, and the same minuteness of detail has not been obtained with the plates when dyed. That such definition can be obtained throughout, is shown by some photographs of fragments of the spectrum recently presented to the Society by Mr. Higgs. It is much to be desired that either he or Mr. Ranyard, who has described his work, would state by what photographic process such photographs of the spectrum are obtained.

The photographs are presented to the Society, and will be placed in the Library.

TABLE.

Section of Photograph.		Angle of Grating from Mean Position.	Mean H.S. Altitude.	Mean L.S. Altitude.	Elastic Force of Aqueous Vapour in inches of Mercury.
		° ′	°	°	
I.	H.S.	13 6	44	...	·39
	L.S.	,,	...	9	·35
II.	H.S.	14 12	41	...	·35
	L.S.	,,	...	7½	·39
III.	H.S.	15 18	44	...	·39
	L.S.	,,	...	7	·46
IV.	H.S.	16 24	52	...	·39
	L.S.	,,	...	7	·39
V.	H.S.	17 30	55	...	·46
	L.S.	,,	...	3½	·26
VI.	H.S.	18 36½	46	...	·24
	L.S.	,,	...	3	·37
VII.	H.S.	19 43	46	...	·29
	L.S.	,,	...	3	·28
VIII.	H.S.	20 50½	55	...	·30
	L.S.	,,	...	5	·37
IX.	H.S.	21 58¼	45	...	·24
	L.S.	,,	...	7½	·37
X.	H.S.	23 6¼	46	...	·24
	L.S.	,,	...	7½	·30
XI.	H.S.	24 14¼	52	...	·30
	L.S.	,,	...	7	·23
XII.	H.S.	25 22¼	47	...	·37
	L.S.	,,	...	7½	·26
XIII.	H.S.	26 10	60	...	·30
	L.S.	,,	...	7	·20

Photograph of the A line in the Solar Spectrum.

By George Higgs.

(*Communicated by the Secretaries.*)

Where the eye begins to fail in ascending towards the more refrangible portions of the solar spectrum, the properties of the haloid salts of silver enable us to continue the thread of research, and in the opposite direction the photographic limits have from time to time been set back as our knowledge of organic chemistry has advanced, till the distinction between the chemical and thermal has ceased to exist. In spite of this, however, an examination of results seems to point to the fact that photography has been slow in adding to the information hitherto gained by eye-observation of such regions which lie on the less refrangible limits of the visible spectrum.

With a view to formulating some process for preparing dried emulsions which shall give certain and uniform results of a great degree of sensitiveness for this region I have for some time been engaged in investigating the properties, and in the preparation in a state of purity, of some of the salts of the anthracene series, an account of which I hope to furnish in its place (belonging as it does more to the domain of Chemistry than to that of Astronomy).

I herewith beg to submit to the notice of Fellows interested a copy of a portion of "Great A" from my Photographic Map of the Normal Solar Spectrum. In order to show as much detail as possible I have had to enlarge about ten diameters, or three times Ångström's scale. The "head" is seen to be composed of about 50 lines. Each line of the pairs composing the fluting or "tail" is a nebulous double. Between the pairs and commencing at w. l. 7622 are to be seen other pairs which are apparently harmonically related to the thicker nebulous pairs. The same region taken with a low Sun of about 86° to 88° zen. dis. exhibits the head as one broad band, disintegration commencing at w. l. 7595 and 7598·5.

Spectroscopic Notes and Queries. By the Rev. A. L. Cortie, S.J.

(*Communicated by E. W. Maunder.*)

I. Has D_3 a coincident dark line in the solar spectrum?

The position of this chromospheric line as given by Young in his list of bright lines is w. l. 5874·9. In some of the spectroscopic maps which I have consulted, dark lines are indicated differing by less than one-tenth metre from the position of the bright line. Ångström (1868) draws a telluric line at 5874·2, followed on the less refrangible side by a band of slight intensity terminated by a well-marked line at 5878·3. Fievez (1882),

whose wave-lengths are based on those of Angström, draws a faint double with w. l. 5875·05 and 5874·7, lines which also appear in Piazzi Smyth's Winchester Solar Spectrum (1884). In Thollon's (1890) splendid atlas several faint lines, apparently of solar origin, are drawn near this position. It will have been remarked that one of the lines drawn by Fievez and Piazzi Smyth differs by only two-tenths of a tenth metre from the position assigned by Young to the chromospheric line. This line also appears on some wonderful photographs of this region of the solar spectrum which I have lately received through the kindness of Mr. Higgs, and which will be referred to later more in detail. The other line, drawn at 5875·05, is photographed as a double. The wave-lengths on the photographs are, of the single 5875·9, and of the double 5876·5, the standard chosen being Mr. Louis Bell's value for the wave-length of D_2, 5890·188, which exceeds by 1·21-tenth metres the number of D_2 on Angström's map. It would appear, then, from a mere examination of these maps that D_3 is exceedingly close to, if not coincident with, a dark line on the solar spectrum.

Trouvelot would make D_3 coincident with a dark line, evidently from his drawing the ray 5874·7 of Fievez, or 5875·9 of the photographs. This drawing occurs in the plate which accompanies his paper, "Sur la structure intime de l'enveloppe solaire" (Bull. Astron. 1885). He remarks: "On a quelquefois affirmé que le spectre normal du Soleil ne contient aucune raie noire correspondant à la raie brillante D_3 du spectre de la chromosphère et des protubérances . . . Ceci est une erreur des plus grandes, car cette raie existe, et, bien qu'elle soit excessivement fine et peut-être variable, il n'y a guère de jours où elle ne soit visible dans notre instrument." Further on he speaks of this line as possessing "la finesse extrême."

These observations would appear to be at variance with those of l'abbé Spée, who, in his paper "Sur la raie dite de l'Helium (Bull. de l'Académie Royale de Belgique, 2^{me} série, tome lxix., No. 5, 1880), writes as follows:—"Dans la région correspondante du spectre, il ne se trouve aucune raie obscure. Huggins, dit à la vérité, avoir vu quelquefois à cette place une légère ligne noire, indice d'un renversement partiel, mais ce phénomène n'a jamais été constaté par les spectroscopistes italiens, et le beau ciel de Rome, l'atmosphère si pure et si transparente de la Sicile, sont, pour ce genre d'observations, des garanties de succès que l'éminent physicien anglais a pu difficilement égaler." Unfortunately he gives no reference to Huggins's paper, so that the opinion of this observer, with regard to the point at issue, cannot be quoted here. But Young would seem to lean to the view that the bright line has ordinarily no corresponding absorption ray. Speaking of an observation of the reversal of D_3 as a dark shade over a sun-spot on September 22, 1870 ("The Sun," ed. 1882, p. 130), he thus writes: "It will

be noticed that . . . . the helium-line D_3, which usually is invisible on the solar surface. . . ."

These discrepancies might be explained if the line in the solar spectrum, with which, according to Trouvelot, D_3 coincides, and which at least is extremely near to it in position, were due to the absorption exercised by our atmosphere. In passing it may be noted as an analogous case that the atmospheric double 5990·01 would also seem to be in close proximity to a bright line in Young's list. Ångström has no solar line on his map nearer to D_3 than the iron line at 5883·03, and he marks 5874·2, the line in question, as an air line. Nor has Cornu drawn any solar line in this region of the spectrum. My own observations taken at Stonyhurst with the Browning automatic spectroscope attached to the 8-inch equatoreal, and in which a dispersion of twelve prisms of 60° was employed, also point to the line being atmospheric. On March 17, 1887, it was not visible, the definition being very good, and the Sun near the meridian. The same was the case at noon on a day in June 1888, when the sky being hazy the definition was only fair. But the line was well seen at 6.15 P.M. on May 28, 1887, when the definition was excellent, twelve other lines also being observed between it and D_2. Three days later, the definition being fair and the sky hazy, these lines about D_3 were all visible at 1.45 P.M., but very much less dark than on the 28th when the Sun was low. The photographs of Mr. Higgs entirely corroborate these observations. They were taken with a Rowland concave grating of 14,438 lines to the inch, and represent the D lines and adjoining portions of the spectrum in a high, intermediate, and low Sun. In the high-sun picture, taken at 2 P.M. on August 17, 1890, the lines about D_3 are just traceable as very faint lines. About twenty lines have been photographed between D_2 and the wave-length in question. In the intermediate-sun picture, taken on September 10, 1889, at 7.30 A.M., the lines about D_3 are much darker, and the total number has increased to about thirty. In the magnificent low-sun photograph, taken on August 30, 1890, at 5.35 A.M., the lines about D_3 are quite conspicuous, being almost as dark as the iron line at 5883·03 of Ångström's map. The total number of lines is now more than fifty. These three photographs alone would lead us to conclude that the line with which D_3 is supposed to be coincident is not of solar origin. But in order to remove all possible doubt, Mr. Higgs photographed, at the end of last October, the E and W limbs of the Sun on two contiguous strips. In this photograph all the lines of solar origin are displaced owing to the Sun's rotation, the air lines remaining unaltered in position. The lines near D_3 are not displaced, being thus proved to be due to our atmosphere. The solar lines nearest to D_3 are a faint pair at 5873·5, and a faint line at 5878, the latter line being the least refrangible of a triplet of which the two other components are air lines. These last two lines are

not visible in the high-sun photograph, and just traceable in that of the intermediate Sun. I would, in passing, allude to a few interesting details which are shown on this last photograph. Thus the strong iron line 5883·03 (Ångström) can be distinctly doubled in one strip, but is shown as a single in the other. No ordinary dispersion would ever have shown that this line is not common to iron and our atmosphere. In one strip the nickel line is widely separated from an air line slightly less refrangible, but almost coincides with it in the other. The mean of five measures made with the Hilger micrometer-microscope by Father Sidgreaves at Stonyhurst gives ·066 mm. as the value for the double displacement corresponding to a velocity for each limb of 1·4 miles per second.

With regard to the coincidence of D_3 with the dark air line as observed by Trouvelot, I would incline to the view that insufficiency of dispersion or displacements in the bright chromospheric line rendered the lines apparently coincident, but that they are really separated by a minute difference of position. The following are a few details of observations taken at Stonyhurst with regard to this point.

March 17, 1887. Time 11.15 A.M.—Definition very good. No dark line seen coincident with D_3.

May 28, 1887. Time 5.30.—Definition very good. Sky slightly hazy. D_3 appeared to be between the close double, but certainly more refrangible than the less refrangible of the pair. Observation very difficult.

Later, 6.15 P.M.—Definition excellent. D_3 certainly between the two lines, and distant by estimation two-thirds of the interval between the dark lines from the less refrangible of the pair.

June 2, 1888, time 12 P.M.—Definition fair. Sky hazy. No line seen coincident with D_3.

September 15, 1890.—D_3 very bright in a small prominence. No black line could be detected coincident with the bright line. Definition fair. Time 12.30 P.M.

September 18, 1890, time 2 P.M.—Definition good. The line at 5875·05 was much blacker and sharper than 5874·7. The latter line was extremely faint and rather fuzzy in appearance. D_3 seemed so close that I could not be absolutely certain that it was not coincident with the less refrangible side of the faint line.

Observations were taken on October 27, 1890, by Father Sidgreaves and Mr. W. McKeon, at 11.30 A.M., and again at 2.40 P.M., with both the Browning automatic and the Hilger direct-vision spectroscopes. The observations were very carefully made by each observer, and with the same result. "No trace of a dark line in perfect coincidence with D_3. Line to the left well defined (i.e. 5875·05 Fievez); to the right no line observed but a kind of hazy band, the space between, and in perfect coincidence with D_3, being intensely bright and without any dark line."

So far, then, as we are warranted by the observations discussed in the present paper, we may conclude:

(1) That D_3 has been seen as dark in a sun-spot.

(2) That there is a faint dark line in the solar spectrum, at least within two-tenths of a tenth metre from the bright line.

(3) That this line is due to our atmosphere.

(4) That observers are disagreed as to whether the dark and bright lines coincide in position.

II. The line Ångström 6676·9.

In the memoir which accompanies the late M. Thollon's recently published exquisite maps of the solar spectrum, the author calls attention to the ray 6676·8 (·9 as it is given in Ångström's catalogue), remarking that it is an interesting fact that this line, one of the feeblest on Ångström's map, is now the strongest in the region B—C. He further identifies the line with 641 of Kirchhoff's map, states that its origin is due to iron, and says that it is often seen in the spectrum of the chromosphere and prominences. He also quotes the authority of M. Dunér in corroboration of his remarks, and reports that the latter spectroscopist considers the line variable, and as varying in intensity with the state of solar activity. I propose to examine the statements of the lamented spectroscopist, as to the identification of the line with Kirchhoff, as to its origin, its coincidence with a bright line in the chromosphere, and as to its variability.

The third point may be passed over at once, as Young gives the line in his list as having a frequency of 25, and a brilliancy of 50 (C = 100, 100), and in the maximum period of solar activity it was frequently seen bright at Stonyhurst.

The first, second, and fourth points are more doubtful. Young in his list of chromospheric lines identifies the line with K 654·3, and at Stonyhurst the line was, when first seen bright in the chromosphere, independently identified as corresponding to this number of Kirchhoff's scale. In the catalogue issued by the British Association in 1878 the corrected w. l. is given as 6677·6, and here also the line is identified with K 654·3. On Kirchhoff's map both 654·3 and 641·0 have an equal intensity and width.

Next, as to the origin of the line. Is it an iron line? In Young's list it is attributed to this element, and also as possibly coincident with a line of barium. But neither in Ångström's map, nor in the catalogues of the spectra of the metals published by the British Association, is there any iron line given in this position. But a barium line is given on the authority of Liveing and Dewar at 6677. At least K 641 is not due to iron, but on the authority of the British Association Catalogue to calcium. The nearest iron line is at 6663·1.

Lastly, as to the variability of the line with the activity of the Sun. Examining such maps and catalogues as I have had access to, the following is the result of the comparison:—Kirchhoff (1861) draws the line as one of the strongest in the region B—C, in Ångström's map (1868) it is one of the faintest. Burton (British Association Catalogue, 1878) makes it one of

the most intense in this region; it is one of the strongest in the map of Fievez (1883), and also in all three strips of the Winchester Solar Spectrum of Piazzi Smyth (1884). Finally, Thollon (1890) draws it as the strongest in this region. It would seem, then, that further evidence is required before we can conclude that the line is really variable, for all authorities except Ångström agree in making the line a strong line.

III. The line Angström 6361·16.

In the Philosophical Transactions of the Royal Society, 1873, No. 163, Part 1, in a paper "On Spectrum-Analysis in connexion with the Spectrum of the Sun," Mr Lockyer gives a long line of zinc at w. l. 6362·5, and remarks, "This line was in the Sun in Kirchhoff's time, but has now dropped out; its number on Kirchhoff's map is 771·7." Turning to the British Association Catalogue for 1878, the observations for which were made by the late Mr. Burton, we find K 771·8 identified with w. l. 6361·41, and its origin attributed to zinc. The number 6361·41 has been obtained from the w. l. 6361·16 as given in Angström's catalogue by applying the correction indicated at p. 29 of his memoir. Burton places the line among the faint lines of the solar spectrum, and it is also drawn as a faint line on Ångström's map. It was therefore to be seen on the Sun in 1861, 1868, and 1878. I have observed the line as widened in Sun-spots five times in 1884, and twice in 1889, and I have no evidence of my own to show that the line was not to be seen in intermediate years.

Note on the Sun-spots of 1888. By E. W. Maunder.

The sun-spots of 1888 were by no means so interesting as those of 1889, for they did not present those strong indications of reviving energy which were seen in the latter year. I have, however, thought that it might possibly be worth while to give year by year some such summary of sun-spot phenomena as I attempted in the paper I read at the April meeting of the Society; and as in this case it would be desirable to do so, not only for future years in their turn, but also for the past years of the Greenwich record, I have commenced with 1888, hoping to follow it with similar notes for the years 1882 to 1887.

Before taking the spots of 1888 I should like to make a slight addition to what I said before concerning the spots of 1889, with the view of strengthening the opinion I then expressed, that the great spot of June 16, 1889, marked the commencement of the new cycle. This may be seen most clearly by dividing the year into two portions: viz., January 1 to June 15, and June 16 to December 31. The latter portion of the year may likewise be further divided into two divisions, the first division including the spots within 10° degrees of the equator, which for the most part may be considered to represent the last efforts of

the old cycle; and the second, the spots distant 20° or more from the equator, which certainly belong to the new cycle, and are its earliest indications. The following table will show strikingly how distinct was the revival both in the mean area of the spots and in their mean distance from the equator after the first half of the year was passed:—

	Mean Daily Spotted Area.	Mean Distance from Equator of all Spots.
		°
1886	381	10·38
1887	179	8 44
1888	89	7·39
1889, Jan. 1 to June 15	18	5·03
1889, June 16 to Dec. 31	130	12·37

If we separate the spots of the last period into two divisions as suggested above, the distinctness of the zone occupied by the spots of the new cycle comes out very clearly:—

Sun-spots from 1889, *June* 16, *to December* 31.

	Mean Daily Spotted Area.	Mean Distance from Equator of all Spots.
		°
Equatorial zone	82	6·59
High latitudes	48	22·41

The increase in area and latitude shown in the equatorial zone in this latter portion of 1889, as compared with the former, was due entirely to one group—the group first seen on June 16—which in its three distinct appearances contributed more than 41 per cent. of the total spotted area of the year. From its position, since it lay in the equatorial zone, this group ought to be reckoned as belonging to the expiring cycle; from its extent and importance, and from the manner in which its appearance was followed by outbursts in the higher latitudes, it may well be reckoned as the first group of the new series.

The duration of the latter groups of 1889 was considerably greater than of the earlier, thus affording a further reason for considering June to be the turning-point. Up to June 15 the mean duration was 7½ days; after June 15 it was 13 days. The number of spot-groups also showed an increase in the latter part of the year. Up to June 15, 10 groups were observed, or, deducting for one reappearance, 9; after June 15 there were 22 groups, or, deducting for reappearances, 17.

Associated with the duration of the groups is their total and mean daily area per group. The mean daily area of a group in 1888 averaged higher than in 1889; but, the lifetime of a group being so much shorter, the total area per group during the entire period of observation was lower in the former year.

	Mean Daily Area per Group.	Total Area per Group.
1888	210	592
1889	140	878
1889, Jan. 1 to June 15	55	294
„ June 16 to Dec. 31	171	1143

This comparison, like the former ones, shows a great increase in energy during the latter part of 1889.

Turning to the sun-spots of 1888, I have already mentioned three features which they presented, in my April paper (*Monthly Notices*, Vol. l., No. 6, p. 361). First, that several characteristics showed that the solar cycle had nearly, but not quite, run out in 1888; for, though that year was inferior to 1887 both as to the number of spot-groups and as to the mean daily area, and presented also a higher number of days without spots, yet in all these three points it had the advantage over 1889, and especially over the first half of it. Secondly, the mean latitude was lower than for 1887; and, thirdly, the average life of a spot was shorter, whilst, as has just been stated, 1889 on the whole, and especially in its latter half, was superior in these points to 1888. The place, therefore, of 1888 in the cycle is very clearly defined. It came almost at the very end, but the actual termination of the old cycle and the beginning of the new one was reserved for 1889. One indication, and one indication alone, was afforded of the coming revival. A very small spot was seen on one day only, in a latitude far outside the zone proper to a period of decline. On December 30 a spot of area 7 was seen in Lat. $-35°{\cdot}5$, 20° further from the equator than any other spot of the year.

Localities of Formation and Dissolution.

Out of the fifty-four separate groups of the year, there were only two cases of reappearance in a second rotation, and in only one of these cases was the group seen a third time. In both instances the formation and dissolution took place in the visible hemisphere. There were thus fifty-one separate groups in 1888. It should be added, however, that two groups had been seen in earlier rotations which fell in 1887. Thus group 2029 of January 1888 had been seen a month earlier in December 1887, and group 2026 was the third appearance of the group which had been seen in 1887 as groups 2017 and 2021.

Of the fifty-one separate groups of the year, thirty formed and dissolved in the visible hemisphere and were seen nly in one rotation, ten of these being seen only on one day. Two formed and dissolved in the visible hemisphere, but were seen in more than one rotation; five formed on this side of the Sun, but were dissipated on the other; eight formed on the other side, but were dissipated on this, one of the eight being seen during more than one rotation: and six of which five were seen only in one

rotation, but the sixth in three, formed and dissolved in the unseen hemisphere. The following table shows how 1888 compares with 1889 in this respect:—

	1888.	1889.
Unseen hemisphere—formations	14	3
„ dissolutions	11	4
Visible hemisphere—formations	37	23
„ dissolutions	40	22

Disregarding spots seen only in the visible hemisphere:—

	1888.	1889.
Visible hemisphere—formations	6	5
„ dissolutions	10	4

The unseen hemisphere, therefore, was decidedly the more prolific of spots of sufficient duration to belong to both hemispheres, whereas in 1889 the balance was the other way.

A very striking difference between 1888 and 1889 is seen when the spotted area of each lune of 13°·2 is taken:—

Lune or Day.	Formations.	Dissolutions.	Ephemeral Spots.	Total Area.
First	0	1	0	1943
Second	5	1	1	2736
Third	3	4	1	3718
Fourth	4	3	2	3728
Fifth	2	2	0	3202
Sixth	3	2	2	2806
Seventh	4	3	0	2663
Eighth	1	3	0	2470
Ninth	1	0	0	2148
Tenth	2	2	4	2333
Eleventh	1	4	0	2291
Twelfth	0	5	0	1837
Thirteenth	1	0	0	862

It will be remarked that, whilst in 1889 there was a steady increase in the spotted area from the east limb of the Sun to the western, in 1888 the case was almost reversed. The maximum area was attained at the third and fourth days, and there was a rapid and fairly regular decline afterwards. The formations, as in 1889, were much more numerous to the east of the central meridian, but, including the "ephemeral" spots, or spots seen only on one day, the dissolutions also were slightly more numerous in the eastern quadrant, whereas in 1889 they had been most frequent in the western.

Distribution in Longitude.

1888 did not afford such an extreme example of concentration of energy in one district as was afforded by the great group of June 16, 1889, but the spotted area was by no means evenly distributed. The most prolific district was that, the centre of which lay in Long. 275° and Lat. −7°. On four distinct occasions a considerable outbreak occupied this region, but in no case did the group return a second time. Group 2052 was the largest group of the year; group 2066, the third in size: but the latter group appeared four rotations later than the former. That the disturbed district was the same was, however, shown by two shortlived and much smaller formations, which were seen in the intermediate rotations. This district embraced 28·4 per cent. of the entire spot-area of the year.

Three other localities contributed about 11 per cent. apiece. Of these one, and the most interesting, had its centre at Long. 298° and Lat. −5°; seven groups, one of them the most permanent of the year, appearing in this district. Throughout 80° of the Sun's circumference the only spots observed lay in one or other of these two districts—*i.e.*, either close to Long. 275°, or close to Long. 298°. Another had its centre in Long. 163°, Lat. −12° Four groups were seen here, two of them large, with an interval of three rotations between the two outbursts. The stability of the centre of disturbance in these three districts, of which I have given the positions, is very remarkable when contrasted with the intermittent character of the actual spot-formations, and the same thing was seen on a minor scale in several other regions. The three districts together comprised more than half the spotted area of the year, and formed the locale of fifteen out of the fifty-one separate groups; yet only in one case was an outbreak sufficiently vigorous to last out a complete rotation.

Note on the Spot-group of 1890 *August* 25–*September* 5.
By E. W. Maunder.

A fine group of sun-spots appeared on the east limb of the Sun on August 25 last. This was the second appearance of the group, which had been observed during the preceding rotation, and it was also seen again during the rotation following, its formation and dissolution taking place in the invisible hemisphere. It was at its second appearance that it attained its greatest size and beauty of detail, and it was at this time that it afforded a threefold example of an apparent rotation round each other of pairs of nuclei, which seemed to me sufficiently well marked to justify a record.

As the group drew away from the east limb it first showed itself, on August 26, as composed of three principal spots. The

following day it had greatly enlarged. Two spots, each of area about 50 millionths, led; then came a confused crowd of small faint spots, and, lastly, a large spot of area about 300, with very dark and distinct nuclei, divided into two principal parts—one to the north, a compact well-defined nucleus; the other to the south, less dark and defined, and interrupted by bright bridges. On August 28 the confused crowd of spots in the middle of the group had crystallised out into a number of well-developed spots, one of which, of irregular outline, was much larger than all the others put together. This spot possessed two large dark nuclei.

These three pairs of nuclei, the two leaders of August 27, and the double nuclei of the great central and following spots of the group, afforded the instances of apparent partial rotation to which I wish to draw attention.

The positions of the three pairs on the days of observation were as follows:—

Preceding Pair.

	Preceding Spot. Longitude.	Latitude.	*Following Spot.* Longitude.	Latitude.
	°	°	°	°
Aug. 27	45·4	+21·0	43·3	+20·4
28	45·7	+20·9	44·2	+20·5
29	46·1	+20·6	45·3	+20·4
30	46·4	+20·5	45·9	+20·6
31	46·9	+20·4	46·5	+20·1

The two spots had coalesced by September 1.

Central Pair.

	Preceding Nucleus. Longitude.	Latitude.	*Following Nucleus.* Longitude.	Latitude.
	°	°	°	°
Aug. 28	42·1	+21·7	41·0	+21·1
29	42·8	+21·2	42·0	+20·7
30	43 6	+21·1	42·9	+20·4
31	44·2	+21·0	44·3	+20·2
Sept. 1	45·1	+20 8	46·3	+20·2

This spot had coalesced with the combined spots of the preceding pair by September 1.

Following Pair.

	Preceding Nucleus. Longitude.	Latitude.	*Following Nucleus.* Longitude.	Latitude.
	°	°	°	°
Aug. 27	35·3	+21·9	35·1	+22·7
28	34·7	+21·9	34·3	+22·6
29	34·2	+21·8	33·7	+22·4
30	33·8	+22·0	33·2	+22·4
31	33·7	+22·1	33·0	+22·4
Sept. 1	33·7	+22·0	32·8	+22·2

The two nuclei were in contact on September 1, and were re-divided later, but in a different manner, by several bright bridges. The axial line of the entire spot continued to move further round on September 2 and 3, in the same direction as before. No photograph of the Sun was taken at Greenwich on September 4.

The following table gives the heliographic position of the "centre of gravity" of the entire group during its second appearance:—

		Heliographic Longitude.	Heliographic Latitude.	Area of Umbræ.	Area of Whole Spots.
		°	°		
Aug.	25	43·2	+20·5	21	66
	26	40·6	+20·9	35	71
	27	38·1	+21·6	82	535
	28	37·9	+21·4	107	724
	29	37·7	+20·9	123	850
	30	38·4	+21·5	131	867
	31	38·6	+21·6	126	901
Sept.	1	39·5	+21·3	155	871
	2	40·7	+21·2	119	837
	3	42·2	+21·1	97	638
	4		No photograph		
	5	44·2	+20·7	51	417

The apparent sway of the group, first backward and then forward again, was due to the rapid growth of the great following spot on the first two or three days, succeeded by the development and forward motion of the central spot later on. By September 1 nearly the whole of the group had been absorbed into these two great spots; but, whilst drawing smaller spots towards themselves, they seemed to exercise a steady repulsion on each other, the average speed of separation being $1\frac{1}{4}°$, or nearly 9,000 miles a day, from August 27 to September 3. Though this divergence was due much more to the forward motion of the first spot than to the retrogression of the second, the line joining their centres, which may be termed the axial line of the group, preserved an almost constant inclination of about 9° to the solar equator.

The following table gives the positions and areas of the two spots for each day of observation:—

		Following Spot. Longitude.	Latitude.	Area.	Central Spot. Longitude.	Latitude.	Area.
		°	°		°	°	
Aug.	26	35·5	+21·7	54	—	—	—
	27	35·2	+22·2	299	39·6	+21·3	133
	28	34·5	+22·2	328	41·0	+21·0	232
	29	34·5	+21·9	475	42·0	+20·8	275
	30	33·8	+22·2	459	42·9	+20·8	335
	31	34·0	+22·4	500	44·4	+20·8	274
Sept.	1	33·7	+22·3	394	46·0	+20·4	362
	2	33·6	+22·3	333	46·4	+20·4	446
	3	33·7	+22·5	217	46·9	+20·3	402
	4			No photograph			
	5	32·9	+22·5	66	46·5	+20·3	347

The following table gives the position-angle of the following nucleus of each pair as referred to the preceding nucleus :—

		Preceding Pair.	Central Pair.	Following Pair.
		°	°	°
Aug.	27	106	—	14
	28	105	299	30
	29	104	302	40
	30	78	315	56
	31	53	17	67
Sept.	1	—	63	78

The rotation of the first pair was, therefore, in the opposite direction to that of the other two. In all three cases, however, the tendency of the movement was to bring spots from the outside of the group nearer towards its general axial line. The well-known tendency of spot-groups is to stretch themselves out in a straight line, which is generally nearly, but not quite, parallel to the equator. The present examples of seeming rotation are, therefore, more correctly examples of the tendency of all formations within a group to range themselves along the axial line, and of spots right and left of that line to move down towards it.

Blackheath,
November 14, 1890.

J.E. Keeler, del. W.H. Wesley, lith.

JUPITER

1890 Aug. 28^{d} 8^{h} 14^{m} P.S.T. 36 in. Refractor of the Lick Observatory.

The Red Spot on Jupiter. By James E. Keeler, B.A.

As the letter of Mr. A. Stanley Williams, in the *Monthly Notices* of June 13, has doubtless directed the attention of many observers to the red spot on *Jupiter*, we may expect a large number of sketches and drawings which will aid in the discussion of the interesting question asked. I send a drawing of the planet, with this region near the centre of the disc, which was prepared from sketches, micrometer measures, and observations of transits of prominent markings, made with the 36-inch equatoreal of the Lick Observatory on the night of August 28. It has also been compared with photographs of *Jupiter*, made with the same instrument by Professor Holden.

But few observations of *Jupiter* have been made with the large telescope this summer, and I have not seen the dark spot to which Mr. Williams called attention (unless it should happen to be one of those shown in the drawing); but according to my past experience, all minor markings, on reaching the red spot, are pushed to one side and flow around it. The drawing which I send may be useful for comparison with others, and may possibly aid in identifying the spot in the modified form which it has doubtless assumed by this time. Mr. Barnard, who has observed *Jupiter* much more systematically than myself, thought the spot referred to by Mr. Williams was gradually dissipated on reaching the red spot. It may be that in flowing around the sides of the latter, its colour was so altered by compression into the narrower limits of the belts surrounding the spot, that it could no longer be recognised.

The accompanying drawing was made under favourable circumstances with a power of about 400. Mr. Barnard, who has lately made many micrometer measures and other observations of the principal markings with the 12-inch equatoreal, agrees with me in considering the drawing an accurate representation of the surface features of the planet at the time given, and it may therefore, as far as it goes, be taken to represent the observations of us both.

The aspect of *Jupiter* has undergone considerable changes during the past year. The long streamers of the equatorial zone, which last summer were the most characteristic feature of the appearance of the planet, seem to be disappearing, and only imperfect examples of them remain. The equatorial zone itself has lost much of its intense whiteness. One of the most striking features at present is the series of small dark spots on the north red belt. When first seen by Mr. Barnard last April they were black, or at least very dark and round; now they are a very deep red, and somewhat elongated in the direction of the belts. Two of these spots are shown in the drawing. The great red spot is of about the same dimensions as last year, and has still a dark shade at its following end, but the middle is whiter, and the

arrangement of belts in the vicinity of the spot is somewhat different. Small round white spots are to be seen on the southern hemisphere, but they are smaller and less conspicuous than they were last summer. Other less obvious changes need not be referred to here, as many more observations of *Jupiter* will be possible during the present opposition. It would seem, on the whole, that the surface features of *Jupiter* indicate less activity in the internal forces of the planet than was manifest a year ago.

Lick Observatory,
August 31, 1890.

Some Experiments relating to the Photometric Comparison of Points of Light with Objects of Sensible Area. By Edmund J. Spitta.

In November 1887 a paper was read before the Society, "On the Appearances presented by the Satellites of Jupiter during Transit," when attention was directed to the fact that whilst using the wedge-photometer during some experiments and measures upon *Jupiter* connected therewith, an unaccountable loss of light was proved to exist when a point of light, such, for instance, as was exhibited by a satellite, was photometrically compared with an object of sensible area like *Jupiter*. For the past three years or more, at the instigation primarily of Professor Pritchard, a protracted research has been in progress to ascertain the cause or causes of such loss, whether physical or physiological; but the subject having extended itself so much further than was anticipated, it has been found necessary to describe the results under three heads: (1) Those connected with the constant of absorption of the wedge-photometer; (2) The objections to employing such a form of photometer when dealing with objects of sensible area and the means devised to remedy the same; and (3) experiments which show peculiar idiosyncrasies in the photoperceptive faculty of the eye when viewing different-sized areas. The object of this communication is to set forth the experiments connected with the last two divisions of the subject.

The results arrived at concerning the first division were presented to the Society in a paper read in March last, but during the progress of the experiments connected therewith, another source of error was thought possibly to cause the loss of light when comparing a point of light with an area in the wedge-photometer. It was this. A point of light, from its very definition, implies that no sensible portion of a wedge is occupied in its passage, but it requires very little thought to perceive that when an area of sensible dimensions is being dealt with this is by no means the case. Moreover, if the area be considerable, the light emanating from its lateral edges impinges on a different thick-

ness of the glass. To supply a correction under these circumstances was not easy, hence the removal of this possible source of error was arrived at by devising an instrument to which the name of "compound wedge-photometer" has been given, and which consists of two thin wedges of neutral tinted glass, made to slide past one another with a uniform rate of motion. Any amount of density (within certain prescribed limits) can be obtained, although a uniformly absorptive area in all parts of the field is rigidly maintained.*

As it became necessary to obtain the coefficient of absorption of this instrument with great precision for use in the experiments to be immediately related, it should be here mentioned that it was evaluated in the following manner.

Each wedge removed from its cell was separately tested for equality in density by the polarising method which peculiarly lends itself to this operation. Both were considered satisfactory. The glasses were then returned to their respective positions, and the coefficient ascertained by employing a small hole illuminated by light immediately under the control of an Abney photometer. By this arrangement the wedge was evaluated by the same method as that employed in its use, which, it would seem, is more philosophical than to evaluate it by equalising lights and use it by a method depending upon extinctions. The artificial star was placed at a distance of 90 inches, and the initial intensity of its light at first arranged so that a ratio of 1 : 8 employed about a third of the available length of the instrument. The value in magnitude over this portion for each half-inch division was found to be ·86. The initial light was then raised and arranged so as to employ the middle third of the wedge, overlapping a small portion of that previously examined. The value here obtained was ·88 mag. for each half-inch division. The last third similarly treated yielded a coefficient for the same length of ·84. These small differences were attributed to errors of observation rather than to any difference in the absorptive power of the glass, hence the mean (·86 mag.) for each half-inch division was adopted in the experiments which follow.

It was found, however, even with the new method of obtaining the coefficient and the new instrument, that a sensible loss of light occurred when a point of light was compared with an area of known dimensions. It was then decided to conduct a further series of experiments which form the third division of the subject, with holes of different sizes, and to ascertain, if possible, the minimum diameter of image at which this loss of light became sensible.

The holes were measured by a parallel wire micrometer, the value of whose screw was first carefully determined, and their respective diameters are given in the following table. The numbers in the first column are for identification only.

* For further information as to details of construction see "A Compound Wedge-Photometer," *Proc. Roy. Soc.*, vol. xlvii.

TABLE I.

Number	1	·0020 inch	Number	7	·0131 inch
,,	2	·0227 ,,	,,	8	·0144 ,,
,,	3	·0027 ,,	,,	9	·0316 ,,
,,	4	·0071 ,,	,,	10	·0460 ,,
,,	5	·0180 ,,	,,	11	·0626 ,,
,,	6	·0380 ,,			

Number 3 being so very nearly the same size as the standard, was not used.

The ratio of the light passing through each of the holes with respect to the first, chosen as the standard, was then obtained with the compound wedge-photometer, and the results are set forth in Table II.

TABLE II.

1.	2.	3.	4.	5.	6.	7.
I.	4	2·72	12·48	1 : 3·58	2·77	12·82
II.	7	4·01	40·37	1 : 6·56	4·08	43·03
III.	8	4·24	49·89	1 : 7·23	4·29	52·27
IV.	5	4·81	84·00	1 : 9·10	4·79	82·81
V.	2	5·19	119·20	1 : 11·36	5·27	129·04
VI.	9	5·70	190·60	1 : 15·60	5·96	243·36
VII.	6	5·636	179·64	1 : 19·00	6·39	361·00
VIII.	10	6·30	400·25	1 : 23·00	6·81	529·00
IX.	11	6·261	319·50	1 : 31·30	7·48	976·60

In column 1 is the distinguishing number affixed to the observation for future reference; in column 2 the identifying number of the hole compared with the standard; column 3 gives the "wedge-interval" converted into magnitude, followed in the next by the same converted into light-ratio; column 5 supplies the real ratio of the diameters from direct measurement, which in columns 6 and 7 is converted into magnitude and light ratio respectively. The holes were all placed at 90 inches from the observing telescope, an achromatic of 2·375 inch aperture with a 24·75 inch focus, armed with an ocular magnifying 46 times.

On examining this table it is seen that until the ratios reached that of 1 : 11, in other words, until the holes, as a matter of fact, had an angular value of more than about 40′ to the eye, they acted as points of light, making due allowance for errors of observation.

The figures in the table are the mean of two closely accordant sets of observations, with the exception of number IX., which is the mean of three.

To understand the results obtained was very difficult, seeing

that every care had been exercised in their execution. During their consideration several other minor experimental measures were made, such as proving whether, with very small holes, readings were similar if the intensity of the light was halved by the Abney photometer but the area doubled. This was done as a check upon the evaluation of the wedge, and it is satisfactory to state that the results obtained were exceedingly accurate, allowing a small error for observation. Of the remainder that were carried out, the following five are selected, as they serve to show successive steps in the process which led to the explanation shortly to follow.

(i) Observation VIII. with the ·046 hole was repeated, but with a higher power ocular; it was found that the enlargement of the image appeared to produce a most striking and important loss in the resulting ratios, amounting as a matter of fact to ·3 magnitude.

(ii) The "wedge reading" of the extinction of the standard was taken with a low power ocular, and then with one of higher power. The difference between them was not more than would be accounted for by the extra thickness of the shorter focussed lenses; hence the teaching of this experiment appeared exactly opposite to that of the preceding.

(iii) The "wedge reading" for extinction was taken for a small hole about ·046 inch in diameter. It was then half-covered and the reading taken again; the difference between these readings gave a ratio of 1 : 87, instead of 1 : 5 as might have been expected, and this after repeating the observations a second time. This seemed very difficult to understand, especially as in the next experiment

(iv) Reducing the intensity by one half in a very small hole (the standard was used) the photometer gave results in accordance with what should have been found.

(v) The last experiment was unique. Two new holes ·047 inch in diameter were obtained. Each was covered with goldbeater's skin. One was left untouched, but to the other was affixed, approximately in its centre, a small disc of brass ·025 inch in diameter, very approximately equivalent to the length of the radius of the larger hole. When the light issuing through the two holes was compared, it was found the spotted area appeared to transmit less light than should be accounted for by the area occupied by the interposed brass disc.

It became evident on consideration that the actual powers of perception in the eye, physiologically speaking, must be a highly important factor in the question at issue, as it seemed very evident the piece of brass in the last experiment occluded more light, so far as was perceived by the brain, than its actual area seemed scientifically to warrant.

When the eye is directed towards an object it is needless to state the image always falls upon the fovea centralis, the central pit which is always present in the macula lutea or yellow spot

of the eye.*† The investigations of Helmholtz, Max Schultze, Henle, Müller,‡ and others, have led very distinctly to the belief that the perceptive faculty of the eye varies very greatly and in ill-defined zones around the fovea, which is by far the most highly sensitive portion of the whole retina. Indeed, Johannes Müller, of Berlin, goes still further, for he states that the perceptive faculty of the eye not only varies in the zones previously mentioned, around the fovea, but even may be said to represent a kind of mosaic, for in the zones themselves it is very unequally diffused. Taking this into consideration then, it became very evident the diameter of the images of these holes upon the retina, or their angular value as seen by the eye, was a most important factor in their capability of perception by the brain. Consequently the diameter of the images of these holes on the retina, when seen with the telescope (of 24·75 inch focus) placed at a distance of 90 inches, with an ocular of magnifying power 46, was computed; the latest value for the focal length of the average eye, viz., ·892 inch, being that employed. The figures obtained are set forth in Table III., side by side with their angular value as seen by the eye:—

TABLE III.

	Inch.		° ′ ″
Hole No. 1	·000943	Angular value	4
„ 2	·010761	„	40 15
„ 3	·001141	„	4
„ 4	·002872	„	12 16
„ 5	·008206	„	31 46
„ 6	·017438	„	1 6 42
„ 7	·005967	„	23 00
„ 8	·006556	„	25 18
„ 9	·014272	„	55 58
„ 10	·020962	„	1 20 30
„ 11	·028455	„	1 49 38

The most recent measures of the fovea centralis in a large number of subjects show that the pit is slightly elliptical, the short axis varying from ·00788 to ·01576 inch, the mean being about ·01182, which implies that the limit of acute vision lies

* It is somewhat curious that the macula lutea is absent in the ox.

† It is interesting to convey to the mind an idea how the size of the fovea limits the area of the most acute vision in daily life. It may be gathered from the fact that such an area lies within the prescribed limits of a halfpenny held at a distance of about 74·5 inches, which implies that the angular value for vision of the highest order is contained within an angle of about 40′, as will be seen hereafter.

‡ Max Schultze, article, "Retina," in Stricker's *Handbook of Histology*; Helmholtz, *Handbuch der Phys. Optik*; Henle, *Quain's Anatomy*, and Henle and Meissner's *Bericht*; Müller, see Huxley's *Crayfish*.

within an angle of about 40′. It is very evident, then, from a comparison of these figures with those in Table II., that the probable reason the first four holes behaved as points of light (for the figures varied nearly as the areas) arose from the fact that the images on the retina fell within the prescribed limits of my fovea, and so within my bounds of acute vision; and that the cause of the falling off of the ratio obtained in observation V. was due to the fact that, owing to the angle subtended being greater than 40′, the diameter of the image of that hole was just beginning to exceed the limits of the pit, a small portion of it falling upon a less sensitive portion of the retina. Hence the total magnitude of the sensuous impression conveyed to the sensorium was less in quantity than if the whole image had fallen entirely within the fovea. The same reasoning applies, but more strikingly still, to the ratios in the observations following, the angles subtended being still greater, the images of the holes were correspondingly larger, and consequently the loss more pronounced. I submit, then, that the cause of the loss of light noticed when *Jupiter* was photometrically compared with his satellites was due to the fact that the angular value of the Jovian image with the ocular employed was greater than 40′, and consequently was due to a physiological idiosyncrasy in the perceptive faculty of the eye.*

I am prepared to admit that the consequence of this is far-reaching, for it is evident, to obtain a veritable photometric comparison in such cases, the images of each object under observation must not subtend an angle of more than 40′—in other words, be small enough to fall within the limits of the observer's fovea centralis.

With this explanation in view, it is not difficult to understand the results obtained in the experiments numbered from one to five.

In the first (I.), the angular value of the larger hole, greater than 40′, became still greater by the subsequent magnification, so the falling off in the total amount of the sensuous impression conveyed to the brain for perception might be reasonably expected to follow.

With (II.) it was different. The enlarged images caused no falling off in the ratios, because they were in each case smaller than the prescribed limit of distinct vision.

In the case of (III.) the half image appeared relatively brighter than the whole, because the ratio of the amount of light falling upon my fovea in the second instance bore a greater proportion to the image in that case to that which it did in the first. In other words, a greater proportion of the image fell upon the extra sensitive pit when the eye was looking at the semi-lune to what it did when viewing the entire one.

With respect to the last observation (V.), it is submitted the theory is more supported than before, for the angular value of

* From a careful consideration, the fovea centralis of my own right eye is very slightly below the average diameter.

the brass disc was such that its image just overlapped the limits of my fovea; hence the spotted area gave to the brain a far less conception of light than it should have, which arose from the fact that the most exciting part of the image was withdrawn.

At this juncture a crucial experiment suggested itself. If the loss of light really did depend upon the size of the image on the retina, then even the pronounced loss which occurred in observation VI., table II., would not be felt if the two holes were viewed without any telescope whatever, for it is patent the images of the two holes must fall within the area of my acute vision. This was done and it is not a little satisfactory to state that the ratios came out very approximately in accordance with the figures given in column 7—in other words, the two holes acted as points of light.

It is not without interest also to mention that the probable cause of the great difficulty experienced by many, including myself, in learning the use of the wedge photometer, is explained by much the same reasoning as the loss of light. Nothing but continued practice will enable the observer to hold his eye sufficiently steady to keep the image of the fading star rigidly within the area of his fovea centralis. But it might be argued by those adhering to predilected orthodoxy, that the explanation submitted lacks support in practice, owing to the fact that it is often supposed to be easier to see a point of light by *oblique* or *indirect* vision than with *direct*. But it is needless to point out that such is more apparent than real, for it must not be forgotten that a retina wearies as much as any other part of the human organism, and, although the fact of suddenly employing a fresh, though perhaps a really weaker, portion of the sensitive membrane would for the moment bring about a more patent effect than the further use of the wearied part, still that does not show that the lateral edges of the retina are intrinsically of greater perceptive power than the fovea. To bear this out it is very easy to make the attempt which I had tried when learning the use of the wedge, long before I was engaged upon these experiments, viz. to direct the eye by *indirect* vision to a faint object, allowing the most intense attention to be employed; the advantage is manifest at once in the seeing, when the observer turns his eye upon the object *directly*. There is no comparison.

In conclusion it should be remarked that, although this idiosyncrasy in the subject of physiological optics, which has such an important bearing in photometrical astronomy, in no way affects the comparison of areas *of the same dimensions*, still it equally applies to *any* form of photometer when points of light are photometrically compared with objects of sensible area. And further, that if any law for the falling off of the light with increasing area had been obtained, it would not be of practical value, as it would probably only apply to the individual observer himself.

Ivy House, Clapham Common,
November, 1890.

On some Celestial Photographs recently taken at Sydney Observatory. By H. C. Russell, B.A., F.R.S.

I have recently obtained a large portrait lens by Dallmeyer (No. 8 in D Series), with lenses having a clear aperture of 6 inches, with the object of taking pictures of the southern part of the Milky Way. While waiting for the lens which is to be used in taking photographs of the part of the sky allotted to Sydney by the Paris Conference, the portrait lens has been attached to the mounting of that telescope and used for taking the desired pictures since the end of June. The weather has, however, been unusually wet and cloudy, and the work has been delayed thereby. Up to the present time pictures have been obtained which include all the bright part of the Milky Way from 10 hours to 17 hours R.A. Also of the Nubeculæ Major and Minor of the bright region in *Sagittarius*, including 8 Messier, and of several other parts.

I send with this positives on glass of six of these photographs covering the Milky Way from 10^h to 17^h, and paper prints of the same. It will be noted that the definition is only good over the central parts. Attempts were made by bringing the lenses closer together to improve the definition, but without success, and the lenses have been used in the mounting supplied by the maker. The plates cover $14° \times 10°$.

The exposure after many experiments was fixed at 3 hours, so that stars of 15 or, in some cases, 16 mag. (Herschel) should be included.

In 3 hours also a faint picture of the nebula about η *Argûs* has been obtained. It shows decided indications of structure, and on the south preceding side of η, two parallel wreaths of nebulæ are distinctly curved, which may be faintly seen in the positive and in the silver print now forwarded; in the negative it is much better seen. η itself seems to be in another spiral wreath, and the faint markings taken together suggest a structure something like that of the spiral nebula, H 1173. The photograph is much under-exposed for the purpose of delineating the nebula, and, unfortunately, when the need for an exposure of 4 or 5 hours was discovered, η was too far west to admit of it, and the solution of the question must rest until η is in a more favourable position. It is remarkable how slow this nebula is in fixing its image on the sensitive plate. I have often tried before with other instruments, but always failed to get any trace of the nebulous light on the plate.

In the great dark oval which is shown near the extreme north of Herschel's drawing of the nebula about η *Argûs*, he shows four minute stars of 16th magnitude. In going over his work with a $7\frac{1}{4}$ inch telescope, I saw three of these stars, and in the photograph obtained in 3 hours three are shown in this oval space, which the photograph shows quite void of other light.

The lemniscate also appears quite void of light except the solitary 15th magnitude star which Herschel speaks of. In the negative, and particularly in the silver print, the lemniscate appears in striking contrast to the bright parts surrounding it.

Generally the photograph bears out the details of Herschel's drawing, especially in parts to which he calls attention; where the outline is limited, as it were, by particular stars; but the scale of the photograph is too small to show the details immediately surrounding η itself.

The peculiar features referred to in this nebula are shown in three negatives, and cannot be accidental; and I feel sure that a longer exposure will reveal additional evidence of the spiral character of the nebula.

Turning now to the limits of the Milky Way, as shown by the photographs, it will be seen that they differ very much from those given in the best drawings. For instance, the boundary, as shown by the two methods, is alike between η and θ *Argûs*, but to the north of η it stretches out far beyond the limit given in drawings. It will be seen, also, that the whole of the stars in the Cross are fully involved in the Milky Way, and the Coal Sack, instead of being a closed space is seen to be open on the south side; this is shown in photographs No. 3 and 3*a*. It also appears that stars are very numerous over three-fourths of it, and that it is only in the extreme north of it that we find that absence of stars which would justify the name.

A cluster of small stars will be noted near the solitary 7th mag. star in this space, which are remarkable for their brightness in the photograph compared with what one sees with the telescope. Altogether, a photograph conveys a picture of the Coal Sack very different from the drawings.

When the photographs are put together (see those mounted on one card), the Coal Sack is seen to extend in relatively dark marking towards and north of β *Centauri*, where it terminates in a space which seems to be absolutely void of stars in a number of photographs which have been taken from it. It is small, about half a degree in diameter, and extends in a curved line for about 2° long.; and in relation to this it is remarkable that the great rift in the Milky Way beginning at α *Centauri* does not appear in the photographs. The stars, it is true, are not quite so abundant there if counted, but when looking at the photograph there is little difference, and certainly nothing like the dark space seen when the eye is turned to the sky at that part.

The grouping and clustering of the stars thus shown in the southern part of the Milky Way are intensely interesting, but an idea of the effect cannot be conveyed in words. It must be seen in the pictures themselves in order to get an idea of what it is like.

Certain it is that these pictures present the Milky Way in an entirely new light, quite different from the telescopic or naked-eye view, and give it such a different aspect that the question arises, which are we to accept?

It seems evident that the photograph may be made to present the stars to us under an aspect quite different from that presented to the eye, because, by continued exposure, the faint stars may have time to produce as much effect as brighter stars, because the effect is limited by the amount of silver in the film, which, when altered by the bright star, stops any further effect of that star, while the faint ones may go on piling up their effect.

The negatives of the bright spot in *Sagittarius* and the Nubeculæ Major and Minor have required upwards of four hours' exposure, and contain a mass of detail; but there has not been time to reproduce them. It may be mentioned, however, that comparatively few of the small nebulæ which are to be found in the Nubecula Major will record themselves in four hours.

The plates used for these photographs were *Extra Rapid Ilford.* It will be seen that nearly all of them have stains along, but not parallel to the margins; these are caused by the tissue paper put between the plates in packing. I have found these plates the most rapid in the market here, and have used them although stained at the margins. I hope the Royal Astronomical Society will allow me to present these pictures of the Southern Milky Way to the Library. I think they are the first of their kind taken in the Southern Hemisphere.

Appendix.

In the preceding notes about photographs of the Milky Way, I referred to others which had been taken, and I am now able to send some positives and silver prints from them, and they are, in some respects, more interesting than those already sent, for they reveal details of structure in the Milky Way and more especially in the Nubeculæ Major and Minor of an unexpected character.

In the first place several photographs of Nubecula Major have been taken with gradually increasing exposures. That taken on Sept. 18th was exposed $5^h\ 2^m$, but owing to passing clouds the effective exposure was only $4\frac{1}{2}$ hours. The negative is good but evidently wanted more exposure, and when looking at it I saw nothing of the spiral structure of the whole, which became evident as soon as a silver print was made. In fact, the whole of this great cloud is a complex spiral nebula with two centres, if I may so express it. One of these is midway between 30 Doradûs and the 6th mag. star at R.A. $5^h\ 23^m$, and 158° 48′ N.P.D. An examination of the positive and silver prints will show the spiral arrangement of stars and nebula and a dark band surrounding this space. The other centre is about two degrees north of this and in same R.A.

So far as I am aware the spiral structure of the Nubecula Major is shown for the first time in these photographs. It was not seen on the negatives, the first of which was taken on Sept. 15th. The im-

pression they gave me was, that a still longer exposure was needed to show the details and numerous small nebulæ. But when on Oct. 1st, I had a silver print made of the negative of the 18th Sept. the spiral structure was evident at the first glance and could then be seen in the negatives.

Something of the same form can be seen in Herschel's Chart of this object, although his drawing is very different, and it is remarkable that his drawing of the Nubecula Major is very like what the photograph shows of Nubecula Minor; that is, a form something like the Dumb-bell nebula. And I have no doubt from the appearance of the Nubecula Minor in several photographs, that a longer exposure will reveal it as a great dumb-bell nebula, a form which seems very definitely indicated in the photographs already taken.

That part of the Milky Way which is situated around γ^2 *Sagittarii* has been photographed several times; because the Sydney photographs, while showing many more stars than the reproduction of Mr. Barnard's photograph, which appears in the Royal Astronomical Society's Notices for March 1890, page 312, taken at the Lick Observatory on August 1, 1889, gives at the same time a very different representation of the relative illumination of different parts. The contrasts are much greater in the picture taken at Mount Hamilton than at Sydney, as this contrast seems to be independent of the number of stars on the plate; it is an interesting question what causes it, because, if not due to the method of reproduction, it is of some importance, in the attempt to make a photographic Chart of the Milky Way, to know what causes the difference. Fortunately for the comparison the lens used at Sydney has so nearly the same focal length as that used at Mount Hamilton, that the photographs can readily be compared. I have sent a positive from the negative taken on September 17, 1890, and exposed $4^h\ 27^m$, another positive from a plate taken October 2, 1890, which was exposed for $4^h\ 2^m$, and thirdly, a negative taken on October 1, 1890, and exposed $3^h\ 32^m$. In passing I may call attention to the fact that on this plate, and all others taken with this lens, the stars outside the limit of good definition are shown as crosses, formed by a streak radiating from the centre of the plate, crossed by a curve like a crescent with its back towards the centre of the plate.

It will be observed that these three pictures of the same object taken on different nights, and with varied periods of exposure, give very nearly the same relative intensity of the various parts of the wonderful structure of this part of the Milky Way, and it will be observed, as already stated, that this contrast differs very much from the reproduction of the Mount Hamilton negative already referred to. The very dark part surrounding γ^2 *Sagittarii* in the Mount Hamilton picture is not found in the Sydney one. The question is one of some importance and can only be fairly discussed when the negatives or direct prints from them can be compared. If this negative, taken on October 1 at

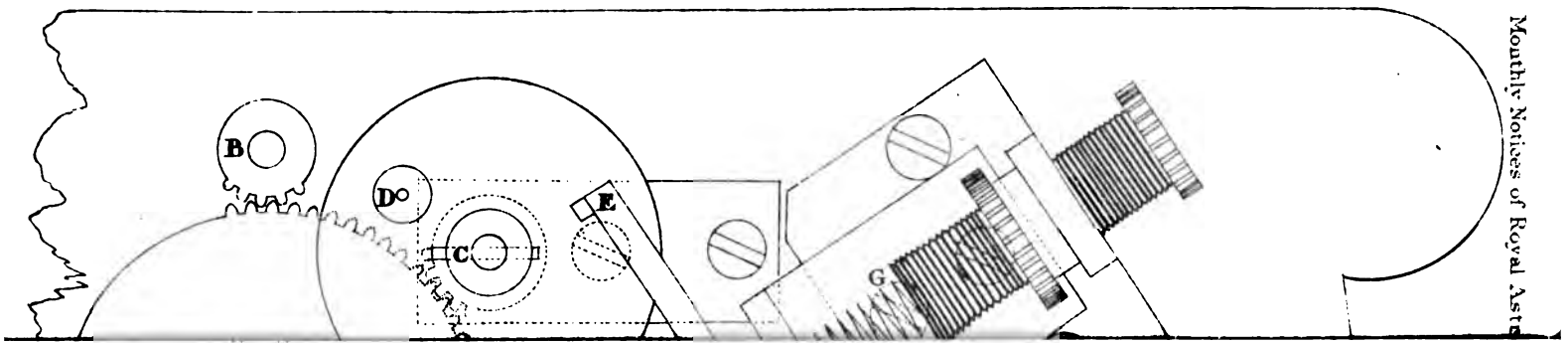

DIAGRAM *showing parts in* ELECTRICAL CONTROL *of observing clock of astro-photographic telescope at Sydney.*

H.C. RUSSELL

Sydney, be examined by the aid of an eyeglass some of the extraordinary details found in this part of the Milky Way, and which is very unlike what I have found in other parts, will be seen. It seems as if one were looking at curve after curve found, farther and farther back in the infinity beyond, like eddies in an infinitely complex vortex, till they end in faint nebulous points of light; which can only just make themselves known after 4 hours of steady impact on the sensitive film.

It would be impossible to convey in words what the photograph shows of the peculiar structure found in the Milky Way at this part, the general character of the arrangement of the stars here may be said to be in curved lines and ellipses, and is quite different from that found in *Argo*, *Crux*, and *Centaur*.

The photographs are placed in the Library.

On an Electrical Control for driving Clocks.
By H. C. Russell, B.A., F.R.S.

At the present time any method which promises to control driving clocks for photographic telescopes satisfactorily is worth discussion, because the complete solution of the difficulty of getting uniform motion for telescopes is very much to be desired, and I hope this will be sufficient excuse for bringing the following notes before you.

The method about to be described does not profess to give absolutely uniform motion, but it does claim so to correct the motion every second as to prevent any error greater than $\frac{1}{100}$ of a second of time. The two photographs herewith will show the general design of the clock, but since any form of clock would serve the purpose, provided one wheel in its train turned in one second, I need not waste time in describing it; except to say that uniform motion is obtained by using two pendulums, and that this form seems to be peculiarly suited to the method of control, for two reasons—first, because uncontrolled it gives remarkably steady-going; and, secondly, because the pendulums are heavy and are not affected by the momentary stoppage of the driving screw (which is connected with the train by friction) which takes place every second.

In selecting a method of controlling this driving clock, it seemed to me better to have the motion of the clock uniformly gaining and stop the excess every second, rather than have one as nearly uniform as possible and correct it when fast or slow, because in the former method all the wheels and working parts are bearing in one direction, and if the screw is stopped by the control, the train goes on, and takes the screw on with it, the moment it is set free by the action of the control. The minute motion which takes place between the train and the screw each second has surprised me very much; but exhaustive experiments

show conclusively that if the driving clock is gaining one second in 200, or from that to so small a quantity as one in 600, the control will catch it and put it right second by second, provided that the control clock makes its contacts with perfect regularity and that the battery power is sufficient to work the control the instant contact is made. Certainly if it does not correct it the exact amount every second, the faults cannot be detected by the means used in these early experiments.

Referring to the photographs it will be seen on B that the screw S (see also photograph A, letter W), for driving the telescope, has at one end a wheel (W) nine inches in diameter, on the rim of which is a worm which has 240 teeth, and as this is required to turn in four minutes it is worked round by a screw which turns round in one second; on the end of this screw is a disc (N in the diagram), which while it can be forced along it by a screw nut M, to adjust the friction between N and H, it cannot turn round it. On the same screw is another disc (H) of like size attached to the wheel (I, 20 teeth), and, excepting the friction between N and H, free to move round the screw. I has the same number of teeth as B, the axis of which is connected direct to the two pendulum governors, and, like B, is driven by the wheel A. The friction between H and N is sufficient to carry the screw G round, against all the friction of moving the large telescope, of which the moving parts weigh two tons. E is a continuation of the armature of the controlling magnet, and in the position shown in the diagram it catches the pin D, which is fixed to the disc N, and stops it, until the current from the controlling clock pulls E down on to the stop X. So long as D is held, I, and of course H, which is attached to it, go on with A and B, and directly D is released it is carried on by the friction between H and N, as the currents come through the magnet every second, D is released once every second, and stopped if it makes a revolution in less than a second. Now, since the screw working into the 240-worm wheel is rigidly attached to N, it follows that once in every revolution it is exactly correct in time, because it cannot pass E until the signal from the control clock comes; and by adjusting the speed of the driving clock it may be made to turn uniformly each time in a little less than one second, so that the pin D just strikes E as it is pulled down by the control, and it is surprising how small an error in the time of rotation of D can be corrected in this way. Some idea of the linear amount of it may be got from the fact that in its revolution D travels two inches, and if it is moving with a gaining rate of one second in 10 minutes, it will be stopped $\frac{1}{600}$ part of 2 inches each time. As already stated, it works most satisfactorily under such circumstances, and the fact of being able to deal with such a small error shows the advantage of having the correction all one way.

Experience shows that it will be an advantage to put D

farther from the axis, so that it travels each second, say, 6 inches, but the chronograph sheets herewith show how satisfactory it is with present arrangement, particularly when the battery is vigorous. See particularly sheet A, and in sheet B, slight variation due to weakness of battery.

The other parts shown in diagram need little explanation. H serves to adjust the strength of the spring C, which lifts the stopping piece E; F adjusts the amount of lift, and K, when screwed down, puts E out of gear.

Two ordinary bottle bichromate batteries supply the current, and it is found that the mercury and alcohol contact is the most satisfactory, and interferes least with the rate of the controlling clock.

I have confined this description to the essential parts required to control the motion of the screw, which turns in one second, and it will be seen that the clockwork driving this may be of any form. The advantages seem to me to be (1) that one has only to make one accurate wheel, the 240-teeth worm wheel; (2) the convenience of controlling a screw that revolves in one second; (3) when correcting any error all the parts are pressing one way.

Note.—When testing the rate under control, a small point was fixed on the screw R (photograph A), and this made a contact at each revolution.

The photographs of the driving clock are placed in the Library.

On the Orbit of 99 Herculis = Alvan Clark 15. By J. E. Gore.

This close and difficult double star was discovered by the late Mr. Alvan Clark at Mr. Dawes's observatory in 1859. Since that year the distance between the components has diminished, and the object is now a difficult one, even with the great refractor of the Lick Observatory. The recorded measures are few, but as a measure by Mr. Burnham this year shows that the companion has described about 298° of its apparent ellipse since its discovery, I have computed the orbit, and find the following provisional elements:—

$P = 53{\cdot}55$ years.	$\Omega = 50°\ 5'$.
$T = 1885{\cdot}58$.	$\lambda = 110°\ 44'$.
$e = 0{\cdot}7928$.	$a = 1''{\cdot}12$.
$i = 38°\ 37'$	$\mu = +6°{\cdot}7222$.

The following is a comparison between the measures and the positions computed from the above elements:—

Epoch.	Observer.	θ_o	θ_c	$\theta_o - \theta_c$	ρ_o	ρ_c	$\rho_o - \rho_c$
		°	°	°	″	″	
1859·63	Dawes	347·1	347·2	−0·1	1·71	1·63	+0·08
1878·46	Burnham	24·4	22·6	+1·8	0·99	1·10	−0·11
1879·468	„	26·5	26·3	+0·2	1·13	1·01	+0·12
1880·455	„	30·1	30·4	−0·3	0·70	0·92	−0·22
1880·613	„	33·1	31·3	+1·8	0·90	0·90	0·0
1881·43	„	29·4	35·7	−6·3	0·51	0·81	−0·30
1888·733	„	"Single with 36-inch refractor"	273·7	...	...	0·60	...
1889·502	„	281·2	281·2	0·0	0·65	0·68	−0·03
1890·49	„	285·1	288·6	−3·5	0·56	0·75	−0·19

According to the above elements the minimum distance between the components occurred about 1885·50, when the position angle was 156°·75 and the distance 0″·18. The angnlar motion of the companion at that time was at the rate of 114° per annum, or about 1° in 3·15 days!

The primary star was measured 5·21 magnitude at Oxford, and 5·36 at Harvard, and the companion was estimated $10\frac{1}{2}$ to 12 by Burnham.

On the assumption that the combined mass of the components is equal to the mass of the Sun, the "hypothetical parallax" would be

$$\pi = a P^{-\frac{2}{3}} = 0''{\cdot}08.$$

Observations of the Variable Star R Carinæ from November, 1886, to June, 1890. By John Tebbutt.

My last-published observations of this interesting variable are to be found in vol. xlvi. of the *Monthly Notices*, and extend from September, 1883, to April, 1886. The following are all the results which I have obtained since April, 1886, and the comparison stars are the same as employed on previous occasions. In my communication above referred to I assigned 312 days as the approximate period from maximum to maximum. Professor Chandler has since discussed the published observations of this star and has arrived at a period of 312·14 days.

Concluded Magnitude of R. Carinæ.

Date.	Mag.	Date.	Mag.	Date.	Mag.
1886, Nov. 16	6·5	1887, April 1	8·7	1887, June 21	8·7
„ Dec. 18	5·4	„ „ 8	8·7	„ July 16	8·4
„ „ 22	5·5	„ „ 23	9·0	„ Oct. 22	5·4
„ „ 27	5·5	„ May 9	9·2	„ Dec. 8	6·9
1887, Jan. 14	5·9	„ „ 24	9·2	„ „ 17	7·8
„ Mar. 17	8·5	„ June 12	9·1	1888, Jan. 2	8·5

Date.	Mag.	Date.	Mag.	Date.	Mag.
1888, Jan. 20	8·7	1888, Dec. 5	8·6	1889, July 22	5·7
„ „ 31	8·8	„ „ 23	9·0	„ Dec. 13	9·2
„ Feb. 7	8·8	1889, Jan. 5	9·1	„ „ 25	9·2
„ „ 16	9·0	„ „ 22	9·2	1890, Jan. 8	9·2
„ „ 21	9·0	„ „ 28	9·0	„ „ 22	8·7
„ Mar. 3	9·1	„ Feb. 21	9·0	„ Feb. 26	8·5
„ „ 8	9·1	„ Mar. 4	8·8	„ Mar. 15	8·1
„ „ 14	9·2	„ „ 21	8·5	„ April 7	5·8
„ „ 19	9·2	„ April 1	8·4	„ „ 11	5·3
„ „ 28	9·1	„ „ 30	7·8	„ „ 18	5·3
„ April 12	9·0	„ June 3	5·2	„ „ 23	5·5
„ „ 18	9·0	„ „ 7	5·0	„ „ 26	5·5
„ „ 27	9·0	„ „ 13	4·9	„ May 7	5·6
„ May 4	8·9	„ „ 17	4·9	„ „ 8	5·7
„ „ 13	8·7	„ „ 21	4·7	„ „ 13	5·8
„ „ 19	8·6	„ „ 24	4·7	„ „ 19	5·9
„ June 8	8·0	„ „ 29	4·9	„ „ 23	6·1
„ „ 12	8·0	„ July 4	5·0	„ June 11	6·6
„ „ 24	7·9	„ „ 7	5·0	„ „ 20	6·8
„ July 5	7·1	„ „ 14	5·0		

Windsor, N.S. Wales :
September 25, 1890.

Observations of the Solar Eclipse of 1890 *June* 16–17, *made at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

The observations of this eclipse with the south-east equatoreal were directed to the determination of the corrections to the Moon's R.A. and N.P.D. and to the semi-diameters of the Sun and Moon. The circumstances of this eclipse were, however, not favourable for determination of corrections to the semi-diameters.

Owing to the cloudy weather it was only possible to make a few observations on the morning of June 17; and though an extended programme of five groups of observations had been drawn up, two groups only were represented in the results, and the corrections to the Moon's R.A. and N.P.D. could not be obtained independently of the corrections to semi-diameters. The following measures were made by Mr. Turner, the declination microscopes being read by Mr. Downing :—

Putting:—

$d\alpha$ = correction to Moon's R.A.

$d\delta$ = correction to Moon's N.P.D.

ds = correction to Moon's Semidiameter.

$d\mathrm{A}$ = correction to Sun's R.A.

$d\Delta$ = correction to Sun's N.P.D.

$d\mathrm{S}$ = correction to Sun's Semidiameter.

(1) From $21^h\ 47^m$ to $22^h\ 5^m$ G.M.T., 6 differences of N.P.D. of p and f cusps were observed, giving

$$-\tfrac{1}{2}d\alpha - d\delta + d\mathrm{S} + ds.$$

(2) From $22^h\ 10^m$ to $22^h\ 16^m$ G.M.T., 4 differences of R.A. of p and f cusps were observed giving

$$-d\alpha + d\mathrm{S} + ds.$$

Two resulting equations were found by taking the sums of the constituent equations in each group, obtained by a comparison of the measured with the tabular quantity as affected by the symbolical corrections $d\alpha - d\mathrm{A}$, $d\delta - d\Delta$, ds and $d\mathrm{S}$:—

$$-20''{\cdot}49 = -1{\cdot}294\,(d\alpha - d\mathrm{A}) - 5{\cdot}970\,(d\delta - d\Delta) + 6{\cdot}822\,ds + 6{\cdot}975\,d\mathrm{S}$$

$$-13''{\cdot}69 = -4{\cdot}046 \qquad -0{\cdot}086 \qquad +4{\cdot}452 \qquad +4{\cdot}397$$

The solution of which is:—

$$d\alpha - d\mathrm{A} = +3''{\cdot}326 + 1{\cdot}081\,ds + 1{\cdot}067\,d\mathrm{S}$$

$$d\delta - d\Delta = +2''{\cdot}711 + 0{\cdot}908\,ds + 0{\cdot}937\,d\mathrm{S}.$$

From observations of the Sun made with the transit-circle on 10 days between May 24 and June 28:—

$$d\mathrm{A} = +0''{\cdot}511 \qquad d\Delta = +0''{\cdot}177$$

Combining this result with that obtained from the equatorial observations during the eclipse, we obtain for the corrections to the tabular place of the Moon in R.A. and N.P.D.:—

$$d\alpha = +3''{\cdot}837 + 1{\cdot}081\,ds + 1{\cdot}067\,d\mathrm{S}$$

$$d\delta = +2''{\cdot}888 + 0{\cdot}908\,ds + 0{\cdot}937\,d\mathrm{S}.$$

From 5 transits of the Sun's diameter and 5 measures of the diameter in N.P.D., made on the morning of June 18, with the same instrument and by the same observers, the apparent corrections to the tabular semidiameter were found to be:—

in R.A. $d\mathrm{S} = -0^s{\cdot}03 = -0''{\cdot}41$

in N.P.D. $d\mathrm{S} = +0''{\cdot}11.$

from which it would appear that $d\mathrm{S}$ is a very small quantity.

The telescope of the South-East Equatoreal has an aperture of 12·8 inches, and a magnifying power of 295 was used.

Royal Observatory, Greenwich:
1890 *November* 13.

Observations of Comet a 1890 (*Brooks*) *made at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

The observations were made with the East or Sheepshanks Equatorial, aperture 6·7 inches, by taking transits over two cross-wires at right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power 60.

Comet a 1890 (*Brooks*).

Greenwich Mean Solar Time.	Observer.	⌀−✱ R.A.	Corr. for Refraction.	⌀−✱ N.P.D.	Corr. for Refraction.	No. of Comp.	Apparent R.A.	Log. factor of Parallax.	Apparent N.P.D.	Log. factor of Parallax.	Comp. Star.
d h m s		m s	s	"	"		h m s		° ′ ″		
Sept. 14 8 22 58	A. D.	+1 8·8	0·0	+ 5 54·0	+0·6	6	...	9·6246	...	0·8162	*a*
8 33 57	,,	+5 43·7	0·0	+ 9 17·7	+1·4	3	13 0 53·9	9·6145	57 46 53·9	0·8251	*b*
8 33 57	υ	+5 17·0	0·0	− 0 29·7	−0·1	3	13 0 57·0	9·6145	57 46 49·4	0·8251	*c*
15 8 3 30	L.	−0 2·5	0·0	+ 2 30·4	+0·2	3	...	9·6298	...	0·8065	*d*
8 27 16	,,	+1 1·6	0·0	+ 0 24·2	0·0	6	...	9·6176	...	0·8229	*e*
8 48 2	,,	+5 23·7	0·0	+11 15·7	+1·6	3	13 1 3·7	9·6055	57 58 36·7	0·8392	*f*
8 48 2	,,	+4 52·3	0·0	− 3 4·3	−0·6	3	...	9·6055	...	0·8392	*g*

Assumed Mean Places of Comparison Stars.

	Star's Name.	R.A. 1890·0.	N.P.D. 1890·0.	Authority.
		h m s	° ′ ″	
a	B.D. + 32°, No. 2317	12 59 4·0	57 41	Bonn Observations, vol. iv.
b	W.B. (2) XII. 1066	12 55 10·43	57 37 37·5	Washington Catalogue, 1860.
c	W.B. (2) XII. 1079	12 55 40·16	57 47 21·9	Weisse's Bessel (2).
d	Anonymous			
e	B.D. + 32°, No. 2319	13 0 1	57 59	Bonn Observations, vol. iv.
f	W.B. (2) XII. 1077	12 55 40·16	57 47 21·9	Weisse's Bessel (2).
g	B.D. + 32°, No. 2313	12 56 12	58 3	Bonn Observations, vol. iv.

Notes.

September 14.—Comet a faint patch of light with distinct stellar nucleus, but difficult to observe.

The observations are corrected for refraction, but not for parallax.

The initials A.D. and L. are those of Mr. Downing and Mr. Lewis respectively.

Observations of Comets made at the Orwell Park Observatory in the years 1889–90. By J. I. Plummer, M.A.

Comet I. 1889 . . . (*Barnard's, Sept.* 2, 1888.)

Date. 1889.	Greenwich Mean Time.	Comet—Star. Δα.	Comet—Star. Δδ.	No. of Comps.	Comet's App. R.A.	Log ($p \times \Delta$).	Comet's App. Dec.	Log ($p \times \Delta$).	Red. to App. Place.	Comp. Star.
	h m s	m s	′ ″		h m s		° ′ ″		s ″	
Feb. 8	6 35 8	+1 8·43	− 2 41·8	5–6	23 42 48·72	9·5137	− 4 34 6·2	0·8523	−1·64 −10·8	1
June 3	13 23 25	−1 6·12	+ 2 15·0	6–6	22 50 57·68	−9·5285	+ 2 40 28·6	0·8350	+0·28 − 1·0	2
19	11 46 28	+2 44·06	+ 3 47·0	8–8	22 17 12·84	−9·5286	+ 2 17 23·9	0·8361	+0·99 + 1·1	3
25	12 15 27	−0 23·99	− 1 2·7	8–8	22 0 37·62	−9·4501	+ 1 52 59·8	0·8342	+1·23 + 3·9	4
26	11 44 16	−3 17·86	− 5 56·6	8–8	21 57 43·78	−9·4840	+ 1 48 6·2	0·8354	+1·26 + 4·2	4
27	12 1 45	+2 49·43	− 2 8·4	8–8	21 54 41·14	−9·4500	+ 1 42 45·1	0·8348	+1·33 + 4·4	5
July 1	11 29 43	−2 16·79	+ 4 1·3	7–7	21 42 9·59	−9·4556	+ 1 19 23·2	0·8366	+1·47 + 5·3	6
22	11 10 2	+2 14·71	+ 2 35·0	7–7	20 27 29·04	−9 0329	− 1 48 16·0	0·8514	+2·07 + 8·7	7

Remarks.

February 8.—Comet faint from moonlight. The wind being very high, the clock was heard with difficulty.
June 3.—The last comparison is rather doubtful, the comet having become faint with the dawn.
June 26.—The intermediate comparisons are rather doubtful, the sky hazy, and even cloudy, at this time.
July 22.—Observations discontinued after this day, the declination axis having become immovable. Resumed on August 29.

Comet V. 1888 . . . (*Barnard's, Oct.* 30, 1888.)

Mar. 25	8 54 46	+1 28·81	+ 9 14·8	7–7	9 20 58·60	−8·1550	+36 20 14·8	0·3733	+0·62 + 1·6	8

Remarks.

March 25.—Comet very faint and difficult to observe, partly owing to the impossibility of excluding all artificial light from the eye.

Comet IV. 1889 . . . (*Davidson's, July* 19, 1889.)

Date. 1889.	Greenwich Mean Time. h m s	Comet—Star. Δα m s	Δδ ′ ″	No. of Comps.	Comet's App. R.A. h m s	Log. (ρ×Δ)	Comet's App. Dec. ° ′ ″	Log. (ρ×Δ)	Red. to App. Place. s ″	Comp. Star.
Aug. 29	9 10 1	+0 28·58	− 1 53·4	8–8	16 11 47·06	9·5103	+24 31 30·6	0·6978	+0·80 +12·5	9
30	9 54 41	−1 23·48	+ 5 26·1	7–7	16 14 11·55	9·5630	+24 57 49·2	0·7278	+0·80 +12·7	10
Sept. 1	9 47 48	+1 18·93	− 2 0·8	8–8	16 18 44·04	9·5628	+25 45 8·2	0·7194	+0·76 +12·9	11
6	9 50 32	−2 28·50	+ 2 45·0	1–1	16 29 30·49	9·5788	+27 26 27·4	0·7165	+0·73 +13·7	12
8	9 59 12	+2 21·09	− 5 28·9	6–6	16 33 38·72	9·5901	+28 0 40·6	0·7229	+0·68 +13·8	13
16	8 7 1	+2 58·28	− 6 7·6	8–8	16 49 17·90	9·4844	+29 53 53·9	0·6181	+0·57 +14·5	14
17	8 50 58	+1 21·84	+ 5 9·7	8–8	16 51 17·04	9·5529	+30 6 28·5	0·6591	+0·57 +14·6	15
18	8 19 2	−1 21·10	+ 0 7·8	8–8	16 53 9·59	9·5131	+30 17 34·6	0·6281	+0·57 +14·7	16
22	9 12 26	−1 49·83	− 9 30·2	8–8	17 0 49·74	9·5889	+31 1 1·9	0·6820	+0·51 +15·0	17
25	7 52 12	+2 36·03	+ 8 22·6	8–8	17 6 23·44	9·4978	+31 29 42·5	0·6014	+0·45 +14·9	18
30	8 33 11	−2 2·61	+ 7 43·5	9–9	17 15 53·19	9·5726	+32 13 33·1	0·6465	+0·41 +15·3	19
Oct. 3	8 32 43	−0 57·86	+ 0 27·5	9–9	17 21 34·42	9·5804	+32 37 15·8	0·6488	+0·36 +15·4	20
12	7 17 17	−3 29·83	− 5 55·3	8–8	17 38 36·62	9·5080	+33 41 25·1	0·5717	+0·26 +15·8	21
14	6 50 49	+3 4·12	− 5 19·0	7–7	17 42 25·72	9·4662	+33 54 41·5	0·5433	+0·20 +15·4	22
18	7 48 56	+1 59·49	+ 6 54·0	7–7	17 50 15·52	9·5743	+34 21 1·7	0·6146	+0·16 +15·4	23
19	7 42 5	+1 30·78	− 0 6·7	8–8	17 52 12·76	9·5691	+34 27 12·7	0·6076	+0·15 +15·5	24
21	10 17 9	−3 42·18	+ 9 10·4	6–6	17 56 20·89	9·6426	+34 40 29·5	0·7845	+0·16 +15·8	25
24	7 20 33	+3 19·73	+ 0 28·9	7–7	18 2 2·42	9·5567	+34 58 26·7	0·5868	+0·08 +15·4	26
Nov. 12	7 29 12	+1 47·20	+ 6 35·6	3–3	18 40 45·42	9·6173	+36 57 44·8	0·6216	−0·08 +15·3	27
13	7 33 43	−0 54·52	− 3 14·6	6–6	18 42 53·00	9·6231	+37 4 14·3	0·6290	−0·08 +15·5	28

Remarks.

September 6.—Comet faint in bright moonlight; interrupted by clouds.

September 8.—Observation not quite satisfactory. Comet too faint in the moonlight.

September 30; October 12.—The R.A. comparisons of this comet are generally difficult to make owing to the elongated form of the nucleus in the direction of the parallel of declination. The individual results, therefore, do not run quite smoothly. The declinations are better.

October 3.—Comet faint in moonlight.

October 18.—Comet faint, sky hazy.

November 12.—Comet faint, invisible after moonrise.

November 13.—Comet faint, observation very doubtful.

Comet V. 1889 . . . (*Brooks's, July* 6, 1889.)

Date.	Greenwich Mean Time.	Comet—Star. Δα.	Δδ.	No. of Compa.	Comet's App. R.A.	Log. (p × Δ).	Comet's App. Dec.	Log. (p × Δ).	Red. to App. Place.		Comp. Star.
1889.	h m s	m s	′ ″		h m s		° ′ ″				
Aug. 29	11 3 12	+1 27·91	+ 3 3·2	6–6	0 6 8·07	−9·3341	− 5 54 43·6	0·8670	+2·19	+15″·1	29
Sept. 1	10 50 3	−2 33·71	+ 0 9·2	7–7	0 5 0·40	−9·3348	− 5 51 7·0	0·8666	+2·22	+15·3	30
16	9 2 46	+1 30·55	− 0 12·1	8–7	23 56 51·81	−9·4220	− 5 32 34·0	0·8618	+2·40	+15·8	31
17	9 43 27	+0 50·98	+ 1 15·3	8–8	23 56 12·25	−9·3209	− 5 31 6·6	0·8658	+2·41	+15·8	31
18	9 6 32	+0 13·05	+ 2 52·6	8–8	23 55 34·32	−9·3972	− 5 29 29·3	0·8629	+2·42	+15·8	31
20	11 59 48	−1 10·11	+ 6 18·4	8–8	23 54 11·18	8·2361	− 5 26 3·4	0·8709	+2·43	+15·8	31
22	10 12 57	−2 25·42	+ 9 40·6	7–7	23 52 55·88	−9·1327	− 5 22 41·2	0·8686	+2·44	+15·8	31
23	10 39 28	+2 47·53	− 4 9·1	2–2	23 52 16·31	−8·9466	− 5 21 2·7	0·8696	+2·45	+15·8	32
25	8 47 51	+1 33·15	− 0 0·1	8–8	23 51 1·94	−9·3680	− 5 16 53·8	0·8633	+2·45	+15·8	32
30	9 37 38	+2 22·06	− 2 46·2	8–8	23 47 57·12	−9·1271	− 5 5 2·6	0·8672	+2·46	+15·8	33
Oct. 1	11 17 15	+1 44·99	+ 0 22·3	8–8	23 47 20·06	8·4661	− 5 1 54·1	0·8688	+2·47	+15·8	33
3	12 15 41	−0 49·49	− 1 36·5	8–8	23 46 12·75	9·1262	− 4 56 2·0	0·8665	+2·47	+15·7	34
14	7 49 59	−1 24·71	+ 0 19·2	8–8	23 41 41·83	−9·3000	− 4 14 48·0	0·8611	+2·44	+15·5	35
17	10 18 43	+3 0·63	− 4 41·5	5–5	23 40 56·68	8·6644	− 4 0 4·9	0·8635	+2·42	+15·4	36
19	8 55 57	+1 43·68	− 3 4·2	9–9	23 40 36·77	−8·8579	− 3 50 15·5	0·8625	+2·41	+15·4	37
21	11 8 40	+1 29·10	+ 8 24·6	8–8	23 40 22·18	9·1694	− 3 38 46·8	0·8602	+2·40	+15·3	37
24	10 19 53	−2 1·08	+ 0 36·5	8–8	23 40 15·49	8·9644	− 3 21 51·3	0·8599	+2·39	+15·3	38
27	10 10 19	+1 38·47	+ 0 40·7	9–9	23 40 25·46	8·9791	− 3 3 19·5	0·8582	+2·36	+15·2	39
30	10 1 36	+1 8·24	+ 1 31·0	4–4	23 40 51·55	8·9970	− 2 43 56·6	0·8564	+2·34	+15·1	40

Remarks.

September 25.—Comet not quite so well seen as previously; the reason of this is not apparent. Sky clear.
October 19.—Two small stars near the comet made the bisections difficult and uncertain. October 30.—Windy, clock difficult to hear.

Comet V. 1889 (continued).

Date.	Greenwich Mean Time.	Comet—Star. Δα.	Δδ.	No. of Comps.	Comet's App. R.A.	Log ($p \times \Delta$).	Comet's App. Dec.	Log ($p \times \Delta$).	Red. to App. Place.	Comp Star.
1889.	h m s	m s	′ ″		h m s		° ′ ″		s ″	
Oct. 31	12 33 22	+1 20·88	− 3 13·2	8–8	23 41 5·59	9·4737	− 2 36 36·8	0·8500	+2·34 +15·1	41
Nov. 12	6 21 42	+1 24·93	−12 37·0	8–8	23 45 49·88	−9·2288	− 1 7 39·8	0·8474	+2·26 +15·0	42
13	6 40 57	+2 0·56	− 4 14·3	8–8	23 46 25·50	−9·1361	− 0 59 17·2	0·8468	+2·25 +14·9	42
15	6 27 43	−1 27·69	−12 6·1	8–8	23 47 40·32	−9·1655	− 0 42 20·3	0·8453	+2·25 +14·9	43
25	6 42 33	+1 0·38	+ 4 55·0	8–8	23 55 27·79	−8·8823	+ 0 47 59·7	0·8367	+2·18 +14·7	44
26	6 45 56	−2 44·53	+ 2 8·4	8–8	23 56 23·05	−8·8209	+ 0 57 34·2	0·8357	+2·20 +14·7	45
Dec. 11	6 25 53	+2 3·94	− 0 4·3	7–7	0 12 29·18	−8·4787	+ 3 28 21·6	0·8196	+2·11 +14·5	46
12	6 54 27	+3 26·21	+ 0 47·5	8–8	0 13 43·70	8·2901	+ 3 39 7·4	0·8183	+2·10 +14·5	47
19	6 56 40	+1 9·16	− 7 44·7	8–8	0 22 43·64	8·7205	+ 4 54 3·6	0·8100	+2·10 +14·4	48
20	6 44 1	+2 28·96	+ 3 8·3	8–8	0 24 3·43	8·5635	+ 5 4 56·5	0·8085	+2·09 +14·3	48
24	8 20 44	−0 34·80	+ 4 10·3	9–9	0 29 38·44	9·2941	+ 5 49 27·4	0·8089	+2·10 +14·2	49
25	9 49 10	+3 13·89	− 1 2·3	8–8	0 31 7·52	9·4784	+ 6 1 19·2	0·8182	+2·07 +14·3	50
1890.										
Jan. 12	6 32 54	+2 0·83	− 8 10·6	9–9	0 58 12·03	9·0354	+ 9 21 37·2	0·7782	−1·07 − 5·6	51
20	7 16 16	+0 59·69	− 0 48·8	9–9	1 11 20·40	9·3009	+10 52 17·5	0·7746	−1·09 − 5·6	52
22	7 50 48	−0 43·56	− 6 7·1	8–8	1 14 43·55	9·3979	+11 14 50·1	0·7798	−1·09 − 5·5	53
Feb. 10	8 2 43	−1 27·46	− 4 32·7	7–8	1 47 48·14	9·4930	+14 43 38·1	0·7733	−1·18 − 5·2	54
11	7 58 59	+0 20·05	+ 6 9·2	8–8	1 49 35·64	9·4913	+14 54 19·9	0·7718	−1·19 − 5·3	54
12	7 16 39	−2 19·76	+ 2 23·2	4–4	1 51 17·1 ±	9·4884	+15 5 19 ±	0·7562	−1·18 − 5·2	55

Remarks.

November 13.—Bisections difficult owing to the neighbourhood of a small star. The companion comet was glimpsed, but the sky was not sufficiently transparent to admit of its observation. November 15.—Failed to see companion comet. Some fog.

November 25.—Again failed to see companion comet with certainty, though perhaps it was glimpsed at times. Windy.

December 19, 25.—Comet faint, sky hazy.

January 12, 20, 22; February 10.—Comet faint and difficult to observe accurately in R.A. The declinations are better.

Comet II. 1889 . . . (*Barnard's, March* 31, 1889.)

Date.	Greenwich Mean Time.	Comet—Star. Δα.	Δδ.	No. of Comps.	Comet's App. R.A.	Log (p × Δ).	Comet's App. Dec.	Log (p × Δ).	Red. to App. Place.	Comp. Star.
1889.	h m s	m s	′ ″		h m s		° ′ ″		s ″	
Sept. 5	14 58 59	−2 5·95	+ 8 19·6	4–4	4 29 6·43	−9·3296	+ 2 44 12·0	0·8277	+ 1·21 + 8·9	56
20	12 45 1	−0 58·52	− 4 2·6	8–7	3 55 42·67	−9·4207	− 2 0 20·0	0·8495	+ 1·77 + 12·1	57
25	11 52 46	+2 16·78	+ 0 35·8	8–8	3 41 16·20	−9·4519	− 3 50 4·0	0·8548	+ 1·96 + 13·2	58
30	11 59 20	+2 23·34	+ 1 42·1	8–9	3 25 4·52	−9·3737	− 5 45 17·8	0·8648	+ 2·13 + 14·0	59
Oct. 21	11 54 15	−1 9·30	+ 8 8·0	1–1	2 5 19·73	−7·7808	−13 17 31·6	0·9037	+ 2·60 + 14·3	60
24	11 57 44	−1 0·08	− 1 38·2	8–8	1 53 44·11	8·5777	−14 6 26·5	0·9062	+ 2·62 + 13·9	61
27	11 13 19	−1 42·91	− 2 21·5	8–8	1 42 35·36	7·4374	−14 49 0·7	0·9089	+ 2·63 + 13·5	62
31	11 40 33	−1 14·70	− 7 34·1	8–8	1 28 8·22	8·9846	−15 37 54·7	0·9089	+ 2·63 + 12·9	63

Remarks.

September 5.—Comet faint and difficult to observe, a small star being near and on the same parallel.
October 21.—Cloudy after this comparison. October 27.—Comet very faint from fog.
October 31.—Comet faint, last two comparisons doubtful.

Comet VI. 1889 . . . (*Swift's, Nov.* 16, 1889.)

Dec. 11	7 5 14	+0 49·63	+ 2 36·2	6–6	23 44 14·81	8·9082	+18 47 26·1	0·6861	+ 1·96 + 19·8	64
12	7 54 59	−2 36·93	+ 5 8·9	8–8	23 47 23·9±	9·2084	+19 5 56±	0·6938	+ 1·99 + 19·9	65
24	9 24 22	−0 46·44	− 4 51·6	9–9	0 26 33·7±	9·4746	+22 22 34±	0·7045	+ 2·14 + 20·0	66

Remarks.

December 11, 12, 24.—Comet very faint, a diffused mass without central condensation. I failed to see this comet on December 20 and 25; a very fine sky is required to see it satisfactorily.

Comet 1890 . . . (*Borrelly's, December* 12, 1889.)

Date.	Greenwich Mean Time.	Comet—Star. Δα.	Comet—Star. Δδ.	No. of Comps.	Comet's App. R.A.	Log ($p \times \Delta$).	Comet's App. Dec.	Log ($p \times \Delta$).	Red. to App. Place.	Comp. Star.
1889.	h m s	m s	′ ″		h m s		° ′ ″		s ″	
Dec. 25	6 46 11	−1 10·15	+ 6 31·7	9–9	18 21 48·33	9·6369	+34 43 44·6	0·8022	−0·26 − 0·3	67

Remarks.

December 25.—Comet fairly bright, with condensation towards the centre, but without true nucleus.

Comet 1890 . . . (*Brooks's, March* 20, 1890.)

1890.										
April 16	14 33 12	−1 25·77	+ 7 27·7	8–8	21 9 22·08	−9·5660	+19 22 37·6	0·7787	−0·64 −14·5	68
22	14 8 25	−1 38·82	+ 0 17·1	8–8	21 6 44·46	−9·5768	+23 19 4·1	0·7573	−0·46 −15·2	69
29	13 34 15	+0 39·71	+ 9 15·0	6–6	21 1 33·35	−9·5967	+28 27 57·5	0·7264	−0·20 −15·9	70
29	13 59 53	+3 18·09	− 3 59·1	4–4	21 1 32·82	−9·5784	+28 28 51·3	0·7035	−0·18 −15·9	71
30	13 48 33	+3 30·97	+ 4 12·0	8–7	21 0 34·27	−9·5868	+29 15 49·3	0·7032	−0·14 −16·0	72
May 1	12 17 21	+1 58·98	− 4 14·5	8–8	20 59 36·19	−9·6234	+30 0 45·6	0·7772	−0·12 −16·1	73
11	11 27 11	+0 49·79	−11 11·9	4–4	20 44 41·01	−9·6684	+38 41 27·5	0·7266	+0·34 −16·7	74
13	10 51 12	+1 21·50	+ 9 22·7	8–8	20 40 27·47	−9·6789	+40 32 38·8	0·7443	+0·45 −16·6	75
14	11 52 49	−1 50·38	+ 5 47·4	8–8	20 38 1·5 ±	−9·6762	+41 32 6 ±	0·6442	+0·48 −16·7	76
15	11 53 58	+1 25·06	+ 2 51·4	7–7	20 35 30·25	−9·6793	+42 29 38·5	0·6229	+0·57 −16·6	77
20	12 33 46	+1 29·87	− 1 59·6	6–6	20 20 21·7 ±	−9·6530	+47 22 46 ±	0·3984	+0·92 −16·1	78
21	10 23 18	−2 22·92	+ 8 38·7	6–6	20 17 4·22	−9·7376	+48 17 53·5	0·6490	+0·96 −16·0	79
21	10 25 56	-1 18·19	+ 1 15·1	5–3	20 17 3·99	−9·7374	+48 17 57·1	0·6443	+0·97 −16·0	80
22	10 23 19	−2 9·76	+ 7 46·3	7–7	20 11 56·7 ±	−9·7459	+49 21 57 ±	0·6224	+1·06 −15·8	81
24	10 17 26	+3 3·23	− 2 8·1	6–6	20 4 3·69	−9·7602	+51 9 11·7	0·5837	+1·27 −15·2	82

Remarks.

May 20.—Observation not quite satisfactory; the star used is double, and the components are almost too wide to admit of its use as one mass.

Comparisons of the Companion of Brooks's Comet with the Main Body.

		h	Δα m s	Δδ ′ ″	Remarks.
Sept.	16	10	+0 20·82	+2 52·5	
	17	10	+0 20·95	+2 55·3	
	18	10	+0 20·59	+2 59·7	Observation not quite satisfactory.
	20	12	+0 20·90	+3 0·7	
	22	10	+0 20 68	+3 2·8	
	25	9	+0 20·89	+3 3·0	Companion not so well seen.
	30	10	+0 20·66	+3 1·2	
Oct.	1	12	+0 20·76	+3 4·1	Small star near, observation difficult.
	17	11	+0 20·75	+2 47·7	Doubtful, excessively faint.
	19	9	+0 18·91	+2 44·3	
	21	12	+0 18·28	+2 46·9	Doubtful, small star near.
	24	11	+0 18·24	+2 41·9	Companion excessively faint.
Nov.	12	7	+0 14·37	+2 21·0	

Assumed Mean Places of Comparison Stars.

Comet I. 1889.

Comp. Star.	R.A. 1889·0. h m s	Decl. 1889·0. ° ′ ″	Authority.
1	23 41 41·93	− 4 31 13·7	Equat. comparison with Glasg. 6237.
2	22 52 3·52	+ 2 38 8·7	Equat. comparisons with B.W.$_1$ 1114 and Schj. 9429.
3	22 14 27·79	+ 2 13 35·8	½ (B.W.$_1$ 247 + Lal. 43571–2 + Lam. 8777).
4	22 1 0·38	+ 1 53 58·6	½ (B.B. vi. + 1°·4584 + Lam. 8689 + Schj. 9020).
5	21 51 50·38	+ 1 44 49·1	½ (B.B. vi. + 1°·4563 + Lam. 8621).
6	21 44 24·83	+ 1 15 16·7	¼ (2 Glasg. 5592 + B.W.$_1$ 1014 + Lam. 8560).
7	20 25 12·25	− 1 50 59·7	½ (B.W.$_1$ 584 + Lam. 7600).

Comet V. 1888.

	9 19 29·17	+36 10 58·4	B.W.$_2$ 359.

Comet IV. 1889.

9	16 11 17·68	+24 33 11·5	Equat. comparison with B.B. vi. + 24°·2983. The place of this star is doubtful. (See catalogue.)
10	16 15 34·23	+24 52 10·4	Equat. comparisons with B.B. vi. + 24°·3000 and B.W.$_2$ 480.
11	16 17 24·35	+25 46 56·1	Equat. comparison with B.B. vi. + 25°·3063.

Comp. Star.	R.A. 1889·0. h	m	s	Decl. 1889·0. °	′	″	Authority.
12	16	31	58·26	+27	23	28·8	Equat. comparison with B.W.$_2$ 991.
13	16	31	16·96	+28	5	55·7	B.W.$_2$ 916. The place of Lal. 30244, which is the same star, does not agree with this, the R.A. being 1^s·23 and the decl. 8″·2 greater. The wires in the Hist. Cel. are not accordant. (See note to Baily's Lalande.) They have probably been unadvisedly altered by Baily.
14	16	46	19·05	+29	59	47·1	50 Herculis. ½ (Gr. 9 yr. 1531 + Yarn. 6980 + Arm.$_1$ 3473).
15	16	49	54·63	+30	1	4·3	Equat. comparison with * 14.
16	16	54	30·13	+30	17	12·1	B.W.$_2$ 1643.
17	17	2	39·06	+31	10	17·0	½ (B.W.$_2$ 3 + Lal. 31201).
18	17	3	46·96	+31	21	5·0	B.W.$_2$ 46.
19	17	17	55·39	+32	5	34·3	½ (B.W.$_2$ 482 + Rümk. 5810).
20	17	22	31·91	+32	36	32·9	B.W.$_2$ 628.
21	17	42	6·19	+33	47	4·6	Equat. comparisons with B.W.$_2$ 1356 and Lal. 32616.
22	17	39	21·40	+33	59	45·2	B.B. vi. + 34°·3031.
23	17	48	15·87	+34	13	52·3	Lal. 32772.
24	17	50	41·83	+34	27	3·9	Equat. comparison with B.W.$_2$ 1658.
25	18	0	2·91	+34	31	3·3	Equat. comparisons with B.W.$_2$ 10 and B.B. vi. + 34°·3122.
26	17	58	42·61	+34	57	42·4	½ (B.W.$_2$ 1839 + B.B. vi. + 34°·3106).
27	18	38	58·30	+36	50	54·0	B.W.$_2$ 1146.
28	18	43	47·60	+37	7	13·5	B.W.$_2$ 1306.
							Comet V. 1889.
29	0	4	37·97	− 5	51	55·5	½ (Glasg. 22 + Yarn. 35 + Gr. 9 yr. 6).
30	0	7	31·89	− 5	51	31·5	½ (B.W.$_1$ 93 + Schj. 48).
31	23	55	18·85	− 5	32	37·7	Yarn. 10604. B.W.$_1$ 1099 is the same star but its R.A. is 0^s·95 greater than that here given.
32	23	49	26·34	− 5	17	9·5	B.W.$_1$ 973. Lal. 46872 is the same star but its decl. is 12″·4 less than that given by Weisse.
33	23	45	32·60	− 5	2	32·2	Equat. comparisons with Yarn. 10499 and B.W.$_1$ 915.
34	23	46	59·77	− 4	54	41·3	B.W.$_1$ 915.
35	23	43	4·10	− 4	15	22·6	½ (Schj. 9844 + Lam. 4773).
36	23	37	53·64	− 3	55	38·8	½ (B.W.$_1$ 736 + Schj. 9800).
37	23	38	50·68	− 3	47	26·7	½ (Arm.$_2$ 3232 + Glasg. 6281 + B.W.$_1$ 755).
38	23	42	14·17	− 3	22	43·1	*Newcomb Standard Cat.* 1083 = 20 *Piscium*.

Comp. Star.	R.A. 1889·0.	Decl. 1889·0.	Authority.
	h m s	° ′ ″	
39	23 38 44·63	− 3 4 15·4	Equat. comparison with Dunsink Cat. 991.
40	23 39 40·97	− 2 45 42·8	Equat. comparison with B.W.$_1$ 812.
41	23 39 42·37	− 2 33 38·7	Equat. comparison with B.W.$_1$ 812.
42	23 44 22·69	− 0 55 17·8	Equat. comparison with B.W.$_1$ 733.
43	23 49 5·76	− 0 30 29·0	½ (Glasg. 6346 + Yarn. 10544 + Gr. 9 yr. 2241).
44	23 54 25·23	+ 0 42 50·1	Equat. comparison with B.W.$_1$ 1002.
45	23 59 5·38	+ 0 55 11·1	½ (Yarn. 10934 + Glasg. 6404 + B.W.$_1$ 1179).
46	0 10 23·13	+ 3 28 11·5	Equat. comparisons with Glasg. 52 and B.B. vi. + 3°·28.
47	0 10 15·39	+ 3 38 5·5	½ (Glasg. 52 + Yarn. 99).
48	0 21 32·38	+ 5 1 33·8	Equat. comparisons with B.W.$_1$ 282 and 285. It is possible that the R.A. of this star is 1 second too great.
49	0 30 11·14	+ 5 45 2·9	Rümk. 234.
50	0 27 51·56	+ 6 2 7·2	Schj. 184.
	1890·0.	1890·0.	
51	0 56 12·27	+ 9 29 53·4	½ (B.W.$_1$ 950 + Yarn. 535).
52	1 10 21·80	+ 10 53 11·9	B.W.$_1$ 119.
53	1 15 28·20	+ 11 21 2·7	½ (B.W.$_1$ 208 + Yarn. 680).
54	1 49 16·78	+ 14 48 16·0	Lal. 3527.
55	1 53 38·1 ±	+ 15 3 1 ±	A.Z. + 14°·321.
		Comet II. 1889.	
56	4 31 11·17	+ 2 35 43·5	Equat. comparison with B.W.$_1$ 633.
57	3 56 39·42	− 1 56 29·5	½ (B.W.$_1$ 1068 + Schj. 1259 + Paris 4684).
58	3 38 57·46	− 3 50 52·9	½ (B.W.$_1$ 709 + Schj. 1135).
59	3 22 39·05	− 5 47 13·8	Equat. comparison with Paris 4059. The star Paris 4059 is also to be found in Weisse's Bessel, Schjellerup, and Lalande, but no two of these authorities agree. Possibly Schjellerup's R.A. is 1 second too small, and the star may have a large proper motion in declination (about −0″·9). The place given in the *Paris Cat.* is used unaltered.
60	2 6 26·43	−13 25 53·9	½ (B.W.$_1$ 59 + Santini 150).
61	1 54 41·51	−14 5 2·2	½ (B.W.$_1$ 945 + Santini 138 + Paris 2502).
62	1 44 15·63	−14 46 52·7	½ (B.W.$_1$ 759 + Santini 119).
63	1 29 20·29	−15 30 33·5	Equat. comparison with Arg. (Oelt.) 987.

Comet VI. 1889.

Comp. Star.	R.A. 1889·0.			Decl. 1889·0.			Authority.
	h	m	s	°	′	″	
64	23	43	23·23	+18	44	30·0	Lamont 1811.
65	23	49	58·8 ±	+19	0	27 ±	A.Z. + 18°·5240.
66	0	27	18·0 ±	+22	27	5 ±	A.Z. + 22°·81.

Comet 1890.

67	18	22	58·73	+34	37	13·2	Lal. 34191.

Comet 1890.

Comp. Star.	R.A. 1890·0.			Decl. 1890·0.			Authority.
	h	m	s	°	′	″	
68	21	10	48·49	+19	15	24·4	½ (Arm.$_2$ 2796 + Rümk. 9068 + Lal. 41312)
69	21	8	23·74	+23	19	2·2	B.W.$_2$ 143.
70	21	0	53·84	+28	18	58·4	½ (Lal. 40906 + Rümk. 8875).
71	20	58	14·91	+28	33	6·4	½ (Rümk. 8837 + B.W.$_2$ 1765).
72	20	57	3·44	+29	11	57·6	Lal. 40763.
73	20	57	37·33	+30	5	16·2	½ (Rümk. 8823 + B.W.$_2$ 1748).
74	20	43	50·89	+38	52	56·2	½ (Yarn. 9323 + Arm.$_2$ 2710).
75	20	39	5·53	+40	23	32·7	B.W.$_2$ 1280.
76	20	39	51·4 ±	+41	26	35 ±	A.Z. + 41°·3868.
77	20	34	4·62	+42	27	3·7	½ (Rad., 4896 + Lal. 39928–30). The observations of Lalande appear to be confirmed by Groombridge, but do not agree well with the *Radcliffe Cat.*, the difference in declination being as much as 13″·3. The mean of these authorities is used with much diffidence.
78	20	18	50·9 ±	+47	25	3 ±	A.Z. + 47°·3089.
79	20	19	26·18	+48	9	30·7	Arg. (Oelt.) 20451.
80	20	18	21·20	+48	16	58·0	Arg. (Oelt.) 20427.
81	20	14	5·4 ±	+49	14	26 ±	A.Z. + 49°·3246.
82	20	0	59·19	+51	11	34·9	B.B. vi. + 51°·2754.

Ipswich: November 10, 1890.

Ephemerides of the Satellites of Saturn, 1890–91. By A. Marth.

(*Continued from p.* 557 *of preceding volume.*)

Differences of right ascension and declination between Titan and Iapetus and the centre of Saturn.

Greenwich Noon.	*Titan.*		*Iapetus.*	
	$\alpha_s - A$	$\delta_s - D$	$\alpha_s - A$	$\delta_s - D$
1890.	s	″	s	″
Dec. 26	−11·35	−17·4	+36·05	−47·6
27	− 8·32	−15·9	36·48	52·7
28	− 4·09	−12·1	36·69	57·4
29	+ 0·76	− 6·5	36·67	61·8
30	+ 5·50	+ 0·1	36·42	65·8
31	+ 9·40	+ 6·6	35·94	69·4
1891.				
Jan. 1	+11·80	+12·2	+35·24	−72·6
2	+12·26	+15·8	34·30	75·3
3	+10·67	+16·7	33·14	77·5
4	+ 7·29	+14·9	31·76	79·1
5	+ 2·70	+10·7	30·16	80·3
6	− 2·34	+ 4·7	28·36	80·9
7	− 7·05	− 2·0	+26·37	−81·0
8	−10·71	− 8·5	24·19	80·5
9	−12·81	−13·8	21·84	79·5
10	−13·09	−17·2	19·34	77·9
11	−11·51	−18·2	16·70	75·8
12	− 8·30	−16·6	+13·93	−73·1
13	− 3·88	−12·7	11·05	70·0
14	+ 1·11	− 6·9	8·09	66·3
15	+ 5·95	− 0·1	5·07	62·2
16	+ 9·87	+ 6·9	+ 2·00	57·6
17	+12·20	+12·7	− 1·10	−52·6
18	+12·53	+16·5	4·20	47·2
19	+10·75	+17·7	7·28	41·5
20	+ 7·17	+15·9	10·31	35·5
21	+ 2·41	+11·5	13·29	29·2
22	− 2·79	+ 5·3	−16·18	−22·8
23	− 7·55	− 1·8	18·97	16·2
24	−11·19	− 8·7	21·63	9·5

Greenwich Noon. 1891.		*Titan.* $\alpha_s - A$	*Titan.* $\delta_s - D$	*Iapetus.* $\alpha_s - A$	*Iapetus.* $\delta_s - D$
		s	"	s	"
Jan.	25	−13·21	−14·4	−24·16	− 2·7
	26	−13·34	−18·1	26·52	+ 4·1
	27	−11·57	−19·3	−28·71	10·8
	28	− 8·15	−17·9	30·71	17·5
	29	− 3·56	−13·9	32·50	24·0
	30	+ 1·57	− 7·8	34·07	30·3
	31	+ 6·47	− 0·6	35·42	36·4
Feb.	1	+10·36	+ 6·8	−36·53	+42·2
	2	+12·57	+13·2	37·40	47·8
	3	+12·71	+17·5	38·03	52·9
	4	+10·72	+18·9	38·40	57·7
	5	+ 6·92	+17·3	38·52	62·1
	6	+ 1·96	+12·8	−38·39	+66·1
	7	− 3·31	+ 6·3	38·01	69·6
	8	− 8·09	− 1·3	37·38	72·6
	9	−11·66	− 8·8	36·51	75·2
	10	−13·54	−15·0	35·40	77·2
	11	−13·47	−19·2	−34·07	+78·7
	12	−11·45	−20·8	32·52	79·7
	13	− 7·87	−19·5	30·76	80·1
	14	− 3·12	−15·4	28·81	80·1
	15	+ 2·13	− 9·1	26·67	79·5
	16	+ 7·01	− 1·3	−24·37	+78·4
	17	+10·81	+ 6·8	21·91	76·9
	18	+12·86	+13·8	19·32	74·9
	19	+12·77	+18·7	16·60	72·4
	20	+10·54	+20·5	13·78	69·4
	21	+ 6·54	+18·9	−10·87	+66·1
	22	+ 1·46	+14·3	7·89	62·3
	23	− 3·87	+ 7·4	4·86	58·2
	24	− 8·61	− 0·7	− 1·80	53·8
	25	−12·06	− 8·8	+ 1·29	49·0
	26	−13·75	−15·7	4·34	+44·0
	27	−13·46	−20·5	7·38	38·8
	28	−11·28	−22·5	10·39	33·3
Mar.	1	− 7·47	−21·3	13·33	27·7
	2	− 2·59	−17·1	16·19	22·0
	3	+ 2·67	−10·4	+18·96	+16·2

Greenwich Noon. 1891.	*Titan.* $\alpha_s - A$	$\delta_s - D$	*Iapetus.* $\alpha_s - A$	$\delta_s - D$
	s	"	s	"
Mar. 4	+ 7·52	− 2·0	+21·61	+10·3
5	+11·18	+ 6·7	24·14	+ 4·3
6	+13·02	+14·4	26·52	− 1·6
7	+12·69	+19·9	28·74	7·4
8	+10·24	+22·0	+30·78	−13·1
9	+ 6·07	+20·6	32·64	18·7
10	+ 0·89	+15·8	34·30	24·2
11	− 4·43	+ 8·5	35·74	29·4
12	− 9·06	− 0·2	36·96	34·4
13	−12·34	− 9·0	+37·95	−39·2
14	−13·81	−16·5	38·71	43·6
15	−13·31	−21·7	39·22	47·7
16	−10·91	−24·0	39·48	51·5
17	− 6·97	−22·9	39·49	55·0
18	− 2·02	−18·5	+39·26	−58·0
19	+ 3·21	−11·4	38·76	60·6
20	+ 7·95	− 2·6	38·02	62·8
21	+11·42	+ 6·8	37·03	64·6
22	+13·03	+15·1	35·79	65·9
23	+12·47	+21·0	+34·32	−66·7
24	+ 9·82	+23·4	32·63	67·1
25	+ 5·53	+22·0	30·72	67·0
26	+ 0·34	+17·0	28·61	66·5
27	− 4·91	+ 9·2	26·31	65·5
28	− 9·39	+ 0·1	+23·83	−64·1
29	−12·46	− 9·2	21·20	62·3
30	−13·72	−17·2	18·42	60·0
31	−13·01	−22·9	15·52	57·3
Apr. 1	−10·46	−25·2	12·52	54·2
2	− 6·43	−24·1	+ 9·43	−50·8
3	− 1·48	−19·5	6·29	47·1
4	+ 3·68	−12·1	+ 3·12	43·1
5	+ 8·26	− 2·8	− 0·08	38·8
6	+11·52	+ 7·0	3·26	34·2
7	+12·90	+15·6	− 6·42	−29·5
8	+12·15	+21·7	9·52	24·6
9	+ 9·34	+24·2	12·55	19·5
10	+ 5·00	+22·7	15·48	14·4

Greenwich Noon. 1891.	*Titan.* $\alpha_s - A$	$\delta_s - D$	*Iapetus.* $\alpha_s - A$	$\delta_s - D$
	s	"	s	"
Apr. 11	− 0·16	+17·5	−18·30	− 9·2
12	− 5·28	+ 9·5	−20·98	− 4·0
13	− 9·58	0·0	23·51	+ 1·2
14	−12·45	− 9·5	25·87	6·3
15	−13·50	−17·7	28·04	11·4
16	−12·62	−23·4	30·02	16·3
17	− 9·97	−25·8	−31·78	+21·1
18	− 5·90	−24·5	33·32	25·7
19	− 1·00	−19·8	34·64	30·1
20	+ 4·03	−12·1	35·71	34·3
21	+ 8·43	− 2·6	36·54	38·2
22	+11·48	+ 7·3	−37·13	+41·8
23	+12·66	+16·0	37·47	45·2
24	+11·73	+22·1	37·56	48·2
25	+ 8·85	+24·5	37·41	50·8
26	+ 4·50	+22·8	37·02	53·1
27	− 0·57	+17·5	−36·39	+55·1
28	− 5·53	+ 9·3	35·53	56·7
29	− 9·64	− 0·3	34·45	58·0
30	−12·30	− 9·8	33·16	58·9
May 1	−13·18	−17·9	31·66	59·4
2	−12·17	−23·4	−29·98	+59·6
3	− 9·47	−25·7	28·12	59·4
4	− 5·43	−24·3	26·10	58·8
5	− 0·62	−19·4	23·92	57·9
6	+ 4·26	−11·7	21·61	56·7
7	+ 8·47	− 2·2	−19·18	+55·1
8	+11·33	+ 7·6	16·64	53·2
9	+12·34	+16·1	14·01	51·1
10	+11·30	+22·0	11·32	48·6
11	+ 8·38	+24·1	8·56	45·9
12	+ 4·09	+22·2	− 5·77	+42·9
13	− 0·86	+16·7	2·95	39·7
14	− 5·66	+ 8·6	− 0·13	36·3
15	− 9·58	− 0·8	+ 2·68	32·7
16	−12·07	−10·1	5·46	28·9
17	−12·82	−17·8	+ 8·21	+25·0
18	−11·75	−23·0	10·89	21·0

Greenwich Noon. 1891.	*Titan.* α_1-A	δ_1-D	*Iapetus.* α_2-A	δ_2-D
	s	″	s	″
May 19	− 9·03	−25·0	+13·50	+16·8
20	− 5·04	−23·3	16·03	12·5
21	− 0·34	−18·3	18·45	8·2
22	+ 4·38	−10·7	+20·76	+ 3·9
23	+ 8·38	− 1·5	22·94	− 0·5
24	+11·11	+ 8·0	24·97	4·8
25	+11·99	+16·0	26·86	9·1
26	+10·89	+21·4	28·58	13·3
27	+ 7·98	+23·1	+30·13	−17·5
28	+ 3·76	+21·0	31·50	21·6
29	− 1·05	+15·5	32·68	25·6
30	− 5·68	+ 7·6	33·66	29·4
31	− 9·44	− 1·5	34·44	33·0
June 1	−11·79	−10·2	+35·01	−36·4
2	−12·45	−17·5	35·38	39·7
3	−11·34	−22·2	35·53	42·7
4	− 8·65	−23·7	35·46	45·5
5	− 4·74	−21·8	35·18	48·0
6	− 0·17	−16·8	+34·69	−50·2
7	+ 4·40	− 9·4	33·98	52·1
8	+ 8·28	− 0·6	33·07	53·7
9	+10·84	+ 8·3	31·96	55·0
10	+11·64	+15·7	30·66	56·0
11	+10·51	+20·4	+29·16	−56·7
12	+ 7·65	+21·7	27·49	57·0
13	+ 3·53	+19·3	25·65	56·9
14	− 1·15	+13·9	23·65	56·5
15	− 5·63	+ 6·2	21·51	55·7
16	− 9·25	− 2·3	+19·24	−54·6
17	−11·49	−10·4	16·85	53·2
18	−12·09	−16·9	14·36	51·4
19	−10·99	−21·0	11·79	49·3
20	− 8·34	−22·0	9·15	46·9
21	− 4·54	−19·9	+ 6·45	−44·1
22	− 0·09	−14·9	3·73	41·1
23	+ 4·34	− 7·8	+ 0·99	37·8
24	+ 8·10	+ 0·5	− 1·75	34·3
25	+10·57	+ 8·5	4·46	30·5

Greenwich Noon. 1891.	*Titan.* $\alpha_s - A$	*Titan.* $\delta_s - D$	*Iapetus.* $\alpha_s - A$	*Iapetus.* $\delta_s - D$
	s	″	s	″
June 26	+11·32	+15·1	− 7·13	−26·5
27	+10·20	+19·1	9·75	22·3
28	+ 7·39	+19·9	12·30	17·9
29	+ 3·38	+17·3	14·75	13·4
30	− 1·17	+11·9	17·10	8·8
July 1	− 5·52	+ 4·7	−19·32	− 4·2
2	− 9·03	− 3·1	21·41	+ 0·5
3	−11·21	−10·4	23·35	5·3
4	−11·78	−16·2	25·14	10·0
5	−10·70	−19·5	26·75	14·7
6	− 8·12	−20·0	−28·19	+19·3
7	− 4·41	−17·7	29·44	23·9
8	− 0·08	−12·8	30·50	28·3
9	+ 4·23	− 6·0	31·37	32·5
10	+ 7·91	+ 1·6	32·03	36·6
11	+10·31	+ 8·8	−32·49	+40·5
12	+11·04	+14·5	32·74	44·2
13	+ 9·95	+17·7	32·79	47·6
14	+ 7·21	+17·9	32·64	50·8
15	+ 3·30	+15·0	32·29	53·7
16	− 1·13	+ 9·8	−31·75	+56·3

Approximate Greenwich times of conjunctions of the satellites with the ends of the ring (*f* conj. with the *following*, *p* with the *preceding* end), *n* north, *s* south of the major axis of the ring. The intervals of time between these conjunctions and the conjunctions with the end points of the equatorial diameter of the ball or the passages through the tangents to the limb at these end points are for Mi. about $1^h{\cdot}8$, En. $1^h{\cdot}9$, Te. $2^h{\cdot}0$, Di. $2^h{\cdot}2$, Rh. $2^h{\cdot}6$.

1890.	h		h		h	
Dec. 27	9·8	Te. fn	Dec. 28 15·2	En. fn	Dec. 29 20·8	Mi. pn
	10·0	Di. w	15·5	Te. fs	22·0	Te. w
	12·2	Mi. fs	16·2	Mi. fn	23·1	Rh. ps
	12·7	En. pn	18·9	Di. e	30 0·1	En. fn
	16·8	Te. pn	20·4	Tit. sup. δ	12·8	Te. fs
	16·9	Rh. fn		s. 7″ Occult.	13·5	Mi. fn
	17·6	Mi. fn	21·6	En. pn	16·2	Di. ps
	22·5	Di. ps	22·2	Mi. pn	16·6	En. ps
	22·8	En. ps.	23·3	Te. e	19·4	Mi. pn
	23·5	Mi pn	29 0·5	Rh. w	20·6	Te. e
28	0·7	Te. w	14·0	Te. pn	22·9	En. fs
	1·9	Rh. pn	14·0	En. fs	31 0·0	Di. fs
	8·6	Te. ps	14·9	Mi. fn	11·4	Te. pn
	10·8	Mi. fs	15·2	Di. pn	12·1	Mi. fn

1890.	h			h			h	
Dec.	31	12·5	Di. e	Jan. 6	15·1	Mi. ps	Jan. 12	18·1 Mi. fn
		15·4	En. pn		19·0	Te. ps		20·1 Di. w
		18·0	Mi. pn		19·3	En. fs		21·3 Rh. fs
		19·3	Te. w		20·2	Di. pn		23·3 En. pn
		23·4	Mi. ps		21·7	Mi. fs	13	8·6 Di. ps
1891.				7	1·3	Rh. w		9·4 En. ps
Jan.	1	1·1	Di. fn		8·7	Di. w		9·5 Te. fn
		1·4	En. ps		9·8	Te. e		11·3 Mi. fs
		10·1	Te. fs		11·8	En. pn		15·7 En. fs
		10·7	Mi. fn		13·7	Mi. ps		16·4 Di. fs
		14·3	Rh. pn		17·6	Te. fn		16·5 Te. pn
		16·6	Mi. pn		19·6	Mi. fs		16·7 Mi. fn
		17·9	En. fn		21·3	Di. ps		18·9 Tit. sup. ♂
		17·9	Te. e		21·8	En. ps		s. 8″. Occult.
		21·4	Di. w		23·9	Rh. ps		19·9 Rh. e
		22·0	Mi. ps	8	0·6	Te. pn		22·6 Mi. pn
	2	0·2	En. pn		8·5	Te. w	14	0·4 Te. w
		1·7	Te. fn		8·9	Rh. fs		15·2 Te. fs
		9·9	Di. ps		12·3	Mi. ps		15·3 Mi. fn
		10·3	En. ps		14·3	En. fn		17·4 Di. fn
		12·9	Rh. w		16·3	Te. ps		18·2 En. ps
		15·2	Mi. pn		17·6	Di. e		18·5 Rh. fn
		16·6	Te. w		18·2	Mi. fs		21·2 Mi. pn
		16·7	En. fs		20·6	En. pn		23·0 Te. e
		17·7	Di. fs		23·3	Te. fs	15	10·7 En. fn
		20·6	Mi. ps		23·6	Mi. fn		13·7 Di. w
	3	0·4	Te. ps	9	7·1	Te. e		13·8 Te. pn
		11·5	Rh. ps		7·5	Rh. e		13·9 Mi. fn
		13·9	Mi. pn		10·9	Mi. ps		17·0 En. pn
		15·2	Te. e		13·1	En. fs		19·8 Mi. pn
		18·7	Di. fn		13·9	Di. pn		21·7 Te. w
		19·2	En. ps		15·0	Te. fn	16	9·5 En. fs
		19·2	Mi. ps		16·8	Mi. fs		10·1 Di. fs
		20·5	Rh. fs		21·9	Te. pn		12·5 Te. fs
		23·0	Te. fn		22·2	Mi. fn		12·5 Mi. fn
	4	11·6	En. fn		23·2	En. fn		18·5 Mi. pn
		12·5	Mi. pn	10	13·6	Te. ps		19·6 En. fn
		13·9	Te. w		14·9	Di. ps		20·3 Te. e
		15·1	Di. w		15·1	Rh. pn		22·6 Di. e
		17·9	Mi. ps		15·5	Mi. fs		23·9 Mi. ps
		18·0	En. pn		15·6	En. ps	17	0·6 Rh. ps
		19·1	Rh. e		20·6	Te. fs		9·6 Rh. ps
		21·7	Te. ps		20·9	Mi. fn		11·1 Di. fn
		23·8	Mi. fs		22·0	En. fs		11·1 Te. pn
	5	10·4	En. fs		22·7	Di. fs		11·2 Mi. fn
		11·1	Mi. pn	11	11·2	Di. e		12·0 En. ps
		11·4	Di. fs		12·2	Te. fn		17·1 Mi. pn
		12·5	Te. e		13·7	Rh. w		18·4 En. fs
		13·1	Tit. inf. ♂		14·1	Mi. fs		18·9 Di. pn
			n 8″ Transit.		14·4	En. pn		19·0 Te. w
	5	16·5	Mi. ps		19·2	Te. pn	18	8·2 Rh. e
		17·7	Rh. fn		19·5	Mi. fn		9·8 Te. fs
		20·3	Te. fn		23·8	Di. fn		9·8 Mi. fn
		20·5	En. fn	12	0·5	En. ps		10·8 En. pn
		22·4	Mi. fs		10·9	Te. ps		15·7 Mi. pn
		23·9	Di. e		12·3	Rh. ps		17·6 Te. e
	6	11·2	Te. w		12·7	Mi. fs		19·9 Di. ps
		12·4	Di. fn		16·9	En. fn		20·9 En. ps
		13·0	En. ps		17·9	Te. fs		21·1 Mi. ps

1891.	h			h			h	
Jan. 19	13·3	En. fn	Jan. 25	23·6	En. fs	Feb. 2	20·0	Te. e
	14·3	Mi. pn		23·9	Di. pn		21·1	Di. fn
	15·8	Rh. pn	26	10·4	Rh. fs	3	10·2	Mi. fn
	16·2	Di. e		12·4	Di. w		10 8	Te. pn
	16·3	Te. w		14·6	Te. fn		15·0	En. fn
	19·7	En. pn	27	8·7	Di. fs		16·1	Mi. pn
	19·7	Mi. ps		9·0	Rh. e		17·4	Di. w
20	12·1	En. fs		13·3	Te. ps		18·6	Te. w
	12·6	Di. pn	28	9·7	Di. fn		21·3	En. pn
	12·9	Mi. pn		11·0	En. ps		21·5	Mi. ps
	14·4	Rh. w		11·9	Te. fn	4	9·4	Te. fs
	14·9	Te. e		13·1	Mi. fs		11·1	Rh. fs
	18·3	Mi. ps		16·5	Rh. pn		13·7	Di. fs
	22·2	En. fn		17·4	En. fs		13·8	En. fs
	22·7	Te. fn		17·5	Di. pn		14·7	Mi. pn
21	11·4	Tit. inf. ♂ n. 9″? Transit		18·5	Mi. fn		17·3	Te. e
				18·9	Te. pn		20·1	Mi. ps
	11·5	Mi. pn	29	9·8	En. pn	5	9·7	Rh. e
	13·0	Rh. ps		10·6	Te. ps		13·3	Mi. pn
	13·6	Te. w		11·7	Mi. fs		14·7	Di. fn
	13·6	Di. ps		15·1	Rh. w		15·9	Te. w
	14·6	En. ps		16·8	Tit. sup. ♂ s. 10″		16·3	En. ps
	16·9	Mi. ps					18·7	Mi. ps
	21·0	En. fs		17·1	Mi. fn		22·5	Di. pn
	21·4	Te. ps		17·6	Te. fs		22·6	En. fs
	21·4	Di. fs		18·6	Di. ps	6	9·2	Tit. inf. ♂ n. 10″
	22·0	Rh. fs		19·9	En. ps			
22	9·9	Di. e	30	9·2	Te. fn		11·0	Di. w
	10·1	Mi. pn		10·3	Mi. fs		12·0	Mi. pn
	12·2	Te. e		12·3	En. fn		14·6	Te. e
	13·4	En. pn		13·7	Rh. ps		15·1	En. pn
	15·5	Mi. ps		14·9	Di. e		17·2	Rh. pn
	20·0	Te. fn		15·8	Mi. fn		17·4	Mi. ps
	20·6	Rh. e		16·2	Te. pn		22·4	Te. fn
	21·4	Mi. fs		18·7	En. pn	7	10·6	Mi. pn
	22·4	Di. fn		21·7	Mi. pn		13·2	Te. w
	23·5	En. ps		22·7	Rh. fs		15·8	Rh. w
23	10·9	Te. w	31	11·1	En. fs		16·0	Mi. ps
	14·2	Mi. ps		11·2	Di. pn		17·6	En. fn
	16·0	En. fn		14·4	Mi. fn		19·9	Di. e
	18·7	Te. ps		14·9	Ti. fs		21·0	Te. ps
	18·7	Di. w		20·3	Mi. pn	8	10·0	En. ps
	19·2	Rh. fn		21·2	En. fn		11·8	Te. e
	20·1	Mi. fs		21·3	Rh. e		14·4	Rh. ps
	22·3	En. pn		22·7	Te. e		14·6	Mi. ps
24	9·5	Te. e	Feb. 1	12·2	Di. ps		16·2	Di. pn
	12·8	Mi. ps		13·0	Mi. fn		16·4	En. fs
	14·8	En. fs		13·5	Te. pn		19·7	Te. fn
	15·1	Di. fs		13·7	En. ps		20·5	Mi. fs
	17·3	Te. fn		18·9	Mi. pn	9	8·8	En. pn
	18·7	Mi. fs		19·9	Rh. fn		10·5	Te. w
25	8·1	Te. w		20·0	Di. fs		13·2	Mi. ps
	11·4	Mi. ps		20·0	En. fs		17·2	Di. ps
	16·0	Te. ps		21·3	Te. w		18·3	Te. ps
	16·1	Di. fn	2	8·5	Di. e		18·9	En. ps
	17·3	En. ps		11·6	Mi. fn		19·1	Mi. fs
	17·3	Mi. fs		12·1	Te. fs	10	9·1	Te. e
	22·7	Mi. fn		12·5	En. pn		11·4	En. fn
	23·0	Te. fs		17·5	Mi. pn		11·8	Mi. ps

1891.	h			h			h	
Feb. 10	13·5	Di. e	Feb. 16	21·1	Di. pn	Feb. 24	20·9	Mi. fs
	17·0	Te. fn		21·7	En. fs	25	11·5	Te. e
	17·7	En. pn	17	9·6	Di. w		13·0	En. fn
	17·7	Mi. fs		13·4	Mi. fn		13·6	Mi. ps
	20·6	Rh. fn		14·1	En. pn		14·6	Di. w
11	7·8	Te. w		14·5	Te. fs		17·1	Rh. w
	9·8	Di. pn		15·1	Rh. ps		19·3	Te. fn
	10·2	En. fs		19·3	Mi. pn		19·4	En. pn
	10·4	Mi. ps		22·2	Di. ps		19·5	Mi. fs
	15·6	Te. ps		22·3	Te. e	26	10·1	Te. w
	16·3	Mi. fs	18	12·0	Mi. fn		10·9	Di. fs
	20·2	En. fn		13·1	Te. pn		11·8	En. fs
	21·7	Mi. fn		16·6	En. fn		12·2	Mi. ps
	22·3	Di. w		17·9	Mi. pn		15·7	Rh. ps
	22·6	Te. fs		18·5	Di. e		17·9	Te. ps
12	10·8	Di. ps		20·9	Te. w		18·1	Mi. fs
	12·7	En. ps		22·7	Rh. e		21·9	En. fn
	14·2	Te. fn	19	9·1	En. ps	27	8·8	Te. e
	14·9	Mi. fs		10·6	Mi. fn		10·9	Mi. ps
	18·6	Di. fs		11·8	Te. fs		11·9	Di. fn
	19·0	En. fs		14·8	Di. pn		14·3	En. ps
	20·3	Mi. fn		15·4	En. fs		16·6	Te. fn
	21·2	Te. pn		16·5	Mi. pn		16·8	Mi. fs
13	11·5	En. pn		19·6	Te. e		19·7	Di. pn.
	11·7	Rh. fs		21·2	Rh. fn		20·7	En. fs
	12·9	Te. ps	20	9·2	Mi. fn	28	7·4	Te. w
	13·6	Mi. fs		10·4	Te. pn		8·2	Di. w
	19·0	Mi. fn		15·2	Mi. pn		9·5	Mi. ps
	19·7	Di. fn		15·8	Di. ps		13·1	En. pn
	19·9	Te. fs		17·9	En. ps		15·2	Te. ps
	21·5	En. ps		18·2	Te. w		15·4	Mi. fs
14	10·3	Rh. e		20·6	Mi. ps		20·8	Di. ps
	11·5	Te. fn	21	9·1	Te. fs		20·8	Mi. fn
	12·2	Mi. fs		10·4	En. fn		21·9	Rh. fn
	14·0	En. fn		12·1	Di. e		22·2	Te. fs
	14·6	Tit. sup. s. 12″ ó		13·8	Mi. pn	Mar. 1	6·0	Te. e
	16·0	Di. w		16·7	En. pn		6·9	Rh. pn
	17·6	Mi. fn		16·9	Te. e		8·1	Mi. ps
	18·5	Te. pn		19·2	Mi. ps		13·9	Te. fn
	20·4	En. pn	22	6·9	Tit. inf. n. 12″ ó		14·0	Mi. fs
15	8·9	Rh. fn		7·7	Te. pn		15·6	En. fn
	10·2	Te. ps		8·4	Di. pn		17·1	Di. e
	10·8	Mi. fs		9·2	En. fs		19·4	Mi. fn
	12·3	Di. fs		12·4	Rh. fs		20·9	Te. pn
	12·8	En. fs		12·4	Mi. pn		22·0	En. pn
	16·2	Mi. fn		15·5	Te. w	2	8·1	En. ps
	16·7	Te. fs	23	9·5	Di. ps		12·2	Tit. sup. s. 14″ ó
	17·9	Rh. pn		11·0	Rh. e		12·5	Te. ps
	22·1	Mi. pn		14·2	Te. e		12·6	Mi. fs
	22·9	En. fn	24	9·6	Rh. fn		13·4	Di. pn
16	8·9	Te. fn		9·6	Mi. pn		14·4	En. fs
	9·4	Mi. fs		10·5	En. pn		18·0	Mi. fn
	13·3	Di. fn		12·8	Te. w		19·5	Te. fs
	14·8	Mi. fn		15·0	Mi. ps	3	6·9	En. pn
	15·3	En. ps		18·3	Di. fn		11·2	Te. fn
	15·9	Te. pn		18·6	Rh. pn		11·2	Mi. fs
	16·5	Rh. w		20·6	En. ps		13·0	Rh. fs
	20·7	Mi. pn		20·6	Te. ps		14·4	Di. ps

1891.	h			h			h	
Mar. 3	16·6	Mi. fn	Mar. 9	19·6	Mi. ps	Mar. 15	17·5	Te. ps
	16·9	En. ps		20·9	En. fn		18·4	Rh. w
	18·2	Te. pn		22·0	Di. e		21·8	Di. fn
	22·2	Di. fs	10	4·5	Tit. inf. δ n. 15″	16	5·6	Di. pn
4	9·4	En. fn		6·9	Mi. fn		7·2	En. fs
	9·8	Te. ps		7·5	Rh. pn		8·4	Te. e
	9·8	Mi. fs		8·7	Te. fs		9·9	Mi. ps
	10·7	Di. e		10·5	Di. fn		15·8	Mi. fs
	11·6	Rh. e		12·8	Mi. pn		16·2	Te. fn
	15·2	Mi. fn		13·3	En. ps		17·0	Rh. ps
	15·7	En. pn		16·5	Te. e		17·3	En. fn
	16·8	Te. fs		18·2	Mi. ps		18·2	Di. w
	21·1	Mi. pn		18·3	Di. pn	17	6·7	Di. ps
5	7·0	Di. pn		19·7	En. fs		7·0	Te. w
	8·2	En. fs	11	6·1	Rh. w		8·5	Mi. ps
	8·4	Te. fn		6·8	Di. w		9·7	En. ps
	8·4	Mi. fs		7·3	Te. pn		14·4	Mi. fs
	10·2	Rh. fn		11·4	Mi. pn		14·5	Di. fs
	13·8	Mi. fn		12·1	En. pn		14·8	Te. ps
	15·4	Te. pn		15·1	Te. w		16·1	En. fs
	18·3	En. fn		16·8	Mi. ps		19·8	Mi. fn
	19·2	Rh. pn		19·4	Di. ps		21·8	Te. fs
	19·5	Di. w	12	6·0	Te. fs	18	5·7	Te. e
	19·8	Mi. pn		10·1	Mi. pn		7·1	Mi. ps
6	7·0	Mi. fs		13·7	Rh. fs		8·5	En. pn
	7·1	Te. ps		13·8	Te. e		9·7	Tit. sup. δ s. 16″
	8·1	Di. ps		14·6	En. fn		13·0	Mi. fs
	10·7	En. ps		15·5	Mi. ps		13·5	Te. fn
	12·5	Mi. fn		15·7	Di. e		15·5	Di. fn
	14·1	Te. fs		21·0	En. pn		18·4	Mi. fn
	15·9	Di. fs		21·4	Mi. fs		18·6	En. ps
	17·1	En. fs		21·6	Te. fn		20·5	Te. pn
	17·8	Rh. w	13	7·1	En. ps	19	4·3	Te. w
	18·3	Mi. pn		8·7	Mi. pn		5·8	Mi. ps
	21·9	Te. e		12·0	Di. pn		8·2	Rh. pn
7	5·7	Mi. fs		12·3	Rh. e		11·0	En. fn
	5·7	Te. fn		12·4	Te. w		11·7	Mi. fs
	9·5	En. pn		13·4	En. fs		11·8	Di. w
	11·1	Mi. fn		14·1	Mi. ps		12·1	Te. ps
	12·7	Te. pn		20·0	Mi. fs		17·1	Mi. fn
	16·4	Rh. ps		20·3	Te. ps		17·4	En. pn
	16·9	Di. fn	14	5·9	En. pn		19·1	Te. fs
	17·0	Mi. pn		7·3	Mi. pn	20	6·8	Rh. w
	19·6	En. ps		10·9	Rh. fn		8·1	Di. fs
	20·6	Te. w		11·1	Te. e		9·8	En. fs
8	9·7	Mi. fn		12·7	Mi. ps		10·3	Mi. fs
	11·4	Te. fs		13·0	Di. ps		10·8	Te. fn
	12·0	En. fn		16·0	En. ps		15·7	Mi. fn
	13·2	Di. w		18·6	Mi. fs		17·8	Te. pn
	15·6	Mi. pn		18·9	Te. fn		19·9	En. fn
	18·4	En. pn		19·9	Rh. pn		20·6	Di. e
	19·2	Te. e		20·8	Di. fs	21	5·4	Rh. ps
	21·0	Mi. ps	15	8·4	En. fn		8·9	Mi. fs
9	8·3	Mi. fn		9·3	Di. e		9·2	Di. fn
	9·5	Di. fs		9·7	Te. w		9·4	Te. ps
	10·0	Te. pn		11·3	Mi. ps		12·3	En. ps
	10·8	En. fs		14·8	En. pn		14·3	Mi. fn
	14·2	Mi. pn		17·2	Mi. fs		14·4	Rh. fs
	17·8	Te. w						

1891.	h			h			h	
Mar.21	16·4	Te. fs	Mar.30	16·4	En. pn	Apr. 7	8·2	Rh. w
	17·0	Di. pn	31	6·8	Di. fs		9·1	Te. ps
22	5·5	Di. w		8·9	En. fs		13·4	Mi. fn
	8·1	Te. fn		10·7	Te. e		15·4	Di. w
	12·9	Rh. e		11·7	Mi. ps		15·5	En. fn
	15·1	Te. pn		13·6	Rh. e		16·1	Te. fs
	18·0	Di. ps		17·6	Mi. fs	8	6·7	Rh. ps
23	6·7	Te. ps		18·5	Te. fn		7·7	Te. fn
	11·5	Rh. fn	Apr. 1	7·8	Di. fn		7·8	En. ps
	13·7	Te. fs		9·4	Te. w		11·7	Di. fs
	14·3	Di. e		10·4	Mi. ps		12·0	Mi. fn
24	5·4	Te. fn		11·2	Rh. fn		14·1	En. fs
	10·6	Di. pn		11·4	En. ps		14·7	Te. pn.
	12·4	Te. pn		15·6	Di. pn		15·7	Rh. fs
	19·1	Rh. w		16·3	Mi. fs		17·9	Mi. pn
	20·2	Te. w		17·2	Te. ps	9	6·4	Te. ps
25	11·0	Te. fs		17·7	En. fs		6·6	En. pn
	11·6	Di. ps	2	8·0	Te. e		10·6	Mi. fn
	17·7	Rh. ps		9·0	Mi. ps		12·8	Di. fn
	18·8	Te. e		10·2	En. pn		13·4	Te. fs
	19·4	Di. fs		14·9	Mi. fs		14·1	Rh. e
26	2·0	Tit. inf. δ n. 16′		15·8	Te. fn		16·5	Mi. pn
				16·6	Di. ps		16·7	En. ps
	7·9	Di. e		19·8	Rh. w		20·6	Di. pn
	9·7	Te. pn		20·3	En. ps		21·2	Te. e
	13·3	Mi. pn		20·3	Mi. fn	10	9·1	Di. w
	13·8	En. pn	3	6·7	Te. w		9·1	En. fn
	17·5	Te. w		7·6	Mi. ps		9·2	Mi. fn
	18·7	Mi. ps		7·7	Tit. sup. δ s. 17″		12·0	Te. pn
	20·5	Di. fn		12·7	En. fn		12·7	Rh. fn
27	8·3	Te. fs		12·9	Di. e		15·1	Mi. pn
	10·9	Mi. pn		13·5	Mi. fs		15·5	En. pn
	16·1	Te. e		14·5	Te. ps		19·9	Te. w
	16·3	En. fn		18·4	Rh. ps		23·8	Tit. inf. δ n. 18″
	16·8	Di. w		18·9	Mi. fn	11	10·7	Te. fs
	17·3	Mi. ps		19·1	En. pn		13·7	Mi. pn
28	7·0	Te. pn	4	9·2	Di. pn		17·9	Di. e
	8·7	En. ps		11·5	En. fs		18·0	En. fn
	8·9	Rh. pn		12·1	Mi. fs		18·5	Te. e
	10·5	Mi. pn		13·1	Te. fn	12	9·3	Te. pn
	13·1	Di. fs		17·5	Mi. fn		10·4	En. ps
	14·8	Te. w		20·1	Te. pn		12·4	Mi. pn
	15·1	En. fs	5	10·3	Di. ps		14·2	Di. pn
	15·9	Mi. ps		10·7	Mi. fs		16·8	En. fs
29	5·6	Te. fs		11·8	Te. ps		17·2	Te. w
	7·5	Rh. w		14·0	En. ps	13	8·0	Te. fs
	7·5	En. pn		16·1	Mi. fn		9·2	En. pn
	9·1	Mi. pn		18·1	Di. fs		11·0	Mi. pn
	13·4	Te. e		18·8	Te. fs		15·3	Di. ps
	14·1	Di. fn	6	6·6	Di. e		15·8	Te. e
	14·5	Mi. ps		9·3	Mi. fs		16·4	Mi. ps
	17 6	En. ps		9·6	Rh. pn	14	6·6	Te. pn
30	6·0	Rh. ps		10·4	Te. fn		9·6	Mi. pn
	7·7	Mi. pn		12·8	En. pn		11·6	Di. e
	10·1	En. fn		14·7	Mi. fn		11·7	En. fn
	10·4	Di. w		17·4	Te. pn		14·5	Te. w
	12·1	Te. w		19·1	Di. fn		15·0	Mi. ps
	13·1	Mi. ps	7	8·0	Mi. fs		18·1	En. pn
	15·0	Rh. fs						

1891.	h				h			h	
Apr. 15	7·9	Di. pn	Apr. 25	14·4	Te. pn	May 5	14·5	Mi. fs
	8·2	Mi. pn		17·0	Mi. pn		16·6	Te. ps
	10·3	Rh. pn		17·2	En. pn	6	7·5	Te. e
	11·5	En. fs	26	8·3	Rh. ps		9·0	Di. e
	13·1	Te. e		9·6	En. fs		9·9	En. fn
	13·6	Mi. ps		9·7	Mi. fn		13·1	Mi. fs
16	8·9	Rh. w		13·1	Te. fs		15·3	Te. fn
	8·9	Di. ps		15·6	Mi. pn		16·3	En. pn
	11·8	Te. w		17·3	Rh. fs		16·7	Rh. e
	12·2	Mi. ps	27	7·6	Di. ps	7	8·7	En. fs
	13·1	En. ps.		8·3	Mi. fn		11·7	Mi. fs
	16·7	Di. fs		11·8	Te. pn		13·9	Te. ps
17	7·5	Rh. ps		12·1	En. ps		15·3	Rh. fn
	10·4	Te. e		14·2	Mi. pn		17·1	Mi. fn
	10·8	Mi. ps		15·4	Di. fs		17·9	Di. w
	11·9	En. pn		15·9	Rh. e	8	10·3	Mi. fs
	16·5	Rh. fs	28	10·4	Te. fs		11·2	En. ps
	16·7	Mi. fs		10·9	En. pn		12·6	Te. fn
	17 8	Di. fn		12·8	Mi. pn		14·2	Di. fs
	18·2	Te. fn		14·5	Rh. fn		15·7	Mi. fn
18	9·1	Te. w		16·5	Di. fn		17·6	En. fs
	14·1	Di. w	29	9·1	Te. pn	9	9·0	Mi. fs
	15·1	Rh. e		11·5	Mi. pn		10·0	En. pn
	16·9	Te. ps		12·8	Di. w		11·3	Te. ps
19	5·4	Tit. sup. δ s. 18″		13·5	En. fn		14·4	Mi. fn
				16·9	Mi. ps		15·2	Di. fn
	7·7	Te. e		16·9	Te. w		18·3	Te. fs
	10·4	Di. fs	30	7·7	Te. fs	10	9·9	Te. fn
	13·7	Rh. fn		9·1	Di. fs		11·5	Di. w
	15·5	Te. fn		10·1	Mi. pn		12·6	En. fn
20	6·4	Te. w		12·3	En. fs		13·0	Mi. fn
	11·5	Di. fn		15·5	Mi. ps		16·9	Te. pn
	14·2	Te. ps		15·5	Te. e	11	7·9	Di. fs
21	7·8	Di. w	May 1	10·2	Di. fn		8·6	Te. ps
	8·2	En. fn		14·1	Mi. ps		11·4	En. fs
	11·2	Mi. fs		14·2	Te. w		11·6	Mi. fn
	12·8	Te. fn		14·8	En. ps		15·6	Te. fs
	14·5	En. pn	2	12·7	Mi. ps		17·5	Mi. pn
	16·6	Mi. fn		12 8	Te. e		20·4	Di. e
22	7·0	En. fs		13·6	En. pn	12	7·2	Te. fn
	9·8	Mi. fs	3	11·3	Mi. ps		8·9	Di. fn
	11·5	Te. ps		11·5	Te. w		10·2	Mi. fn
	15·2	Mi. fn		11·9	Rh. pn		12·7	Rh. pn
	16·6	Di. e		15·3	Di. e		13·9	En. ps
	17·0	En. fn		16·1	En. fn		14·2	Te. pn
	18·5	Te. fs		17·2	Mi. fs		16·1	Mi. pn
23	10·1	Te. fn	4	8·6	En. ps		16·7	Di. pn
	12·9	Di. pn		9·9	Mi. ps		20·3	En. fs
	17·1	Te. pn		10·2	Te. e		20·4	Tit. inf. δ n. 18″
24	8·8	Te. ps		10·5	Rh. w			
	11·1	Rh. pn		11·7	Di. pn	13	8·8	Mi. fn
	14·0	Di. ps		14·9	En. fs		11·3	Rh. w
	15·8	Te. fs		15·9	Mi. fs		12·7	En. pn
25	7·4	Te. fn	5	3·7	Tit. sup. δ s. 18″		12·9	Te. fs
	9·7	Rh. w					14·7	Mi. pn
	10·3	Di. e		8·8	Te. w		17·8	Di. ps
	10·8	En. fn		9·1	Rh. ps		20·1	Mi. ps
	11·1	Mi. fn		12·7	Di. ps		20·7	Te. e

1891.	h		h		h
May 14	9·9 Rh. ps.	May 14	18·9 Rh. fs	May 15	14·0 En. fs
	11·5 Te. pn		19·4 Te. w		17·4 Mi. ps
	13·4 Mi. pn	15	7·7 En. ps		17·5 Rh. e
	14·1 Di. e		10·2 Te. fs		18·0 Te. e
	15·2 En. fn		10·4 Di. pn		
	18·8 Mi. ps		12·0 Mi. pn		

Note on Errata to Vol. II. of Oppolzer's 'Bahnbestimmung' recently published in the 'Monthly Notices.' By Lieut.-Gen. J. F. Tennant, R.E., F.R.S.

In Vol. l., p. 472 of the *Monthly Notices* I have given some errata to the volume of Oppolzer's great work. Since then Mr. Leuschner, of the Lick Observatory and University of California, has given a very extensive list, and has referred to my errata, as to some of which he expresses doubt.

I am sorry to say that the correction of sign in the formula in page 108 is erroneous. And as regards that given for p. 148, though correctly copied from my note, it must have had a wrong reference, for it evidently cannot refer to this page.

In the value of log. fig. 3, p. 111, Mr. Leuschner gives a correction of sign, but no correction to the figures. The subscript n had been erased in my copy, and so missed my notice; but the change of a figure is necessary, and so are all the rest of the numerical corrections. Also the sign of $\Delta \Sigma (x)$ on Oct. 27 should be $+$.

Mr. Leuschner has performed a service to students, who will, it is to be hoped, be saved some doubts when going carefully through this work.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LI. DECEMBER 12, 1890. No. 2

Lieut.-General J. F. TENNANT, C.I.E., R.E., F.R.S., President, in the Chair.

The Rev. John Mitchell, B.D., 57 Parkgate Road, Chester, was balloted for and duly elected a Fellow of the Society.

Lewis Boss, Dudley Observatory, Albany, N.Y., U.S.A.;
A. Cornu, Paris; and
C. Souillart, Lille,

were balloted for and duly elected Associates of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

George Price Blackwood Hallowes, Surveyor of the Post Office, 77 Lansdowne Road, Didsbury, Manchester (proposed by E. J. Spitta);

Shin Hirayama, Astronomer at the Tokyo Observatory, Japan (proposed by W. H. M. Christie);

Robert John Pearce, M.A. Cantab., Hon. D.C.L. Durham, Professor of Mathematics in Durham University (proposed by the Rev. T. E. Espin);

John M. Stone, St. John's College, Cambridge (proposed by the Rev. A. Wrigley).

Seventy-two Presents were announced as having been received since the last meeting, including, among others,

Ahmed Mukhtar Pasha, The Reform of the Calendar (in the original Turkish), presented by Sir J. W. Redhouse.

Celestial photographs taken at the Sydney Observatory, presented by H. C. Russell.

Observations of the Spectra of Sun-spots in the Region B—D made at the Stonyhurst College Observatory in the years 1882–89. By the Rev. A. L. Cortie, S.J.

(*Communicated by E. W. Maunder.*)

(*Abstract.*)*

The paper contains the results derived from the detailed study of the spectra of ninety Sun-spots in the region B—D. The observations were made after the plan followed at Greenwich, and the instrument employed was the Browning automatic spectroscope, generally with a dispersion of twelve prisms of 60° attached to the 8-inch equatoreal.

In the discussion the observations are divided into two periods, the first embracing the disturbed period of solar activity from 1882 till the autumn of 1886; and the second, called the quiet period, that from the autumn of 1886 till June 1889.

The widening of the lines has, as far as possible, been reckoned in tenths of the normal breadth of the lines. For the sake of comparison of the observations among themselves, two standards have been chosen, and a line widened between the limits 0·5 and 1·0 of its normal breadth is called a "more widened line," and that widened 1·0 or more a "most widened line." Lines below 0·5 are simply "widened." A long table gives the mean widening of nearly three hundred lines between B and D, both for the disturbed and the quiet period. Any interesting points about the lines are noted in a column headed "Remarks."

The main conclusions deduced from the discussion of these observations may be summarised as follows:—

1. The general absorption due to a spot occasionally varies in intensity in different portions of the spectrum. Two or three times it has been so dark at the red end as to partially mask the selective absorption of the lines. The spot-bands observed in 1885 and the first half of 1886 have not been seen in any spot observed from the autumn of 1886 to the autumn of 1890.

2. Of fifty-three iron lines occurring in this part of the spectrum, in the disturbed period only one had a mean widening placing it among the more widened lines.

3. In a total of 1,228 observations, the large majority having been taken in the disturbed period, only three in the disturbed period, and fourteen in the quiet period, placed iron lines among the most widened lines.

4. In the quiet period many more iron lines appeared among the more widened lines than in the disturbed period. Comparing the totals, 126 observations in 1885, and 127 in 1889, only three times in the former year was iron among the more widened lines, against eighty-one times in the latter year.

* To be published in the *Memoirs*, vol. l.

5. In general the iron lines seen bright in the chromosphere by Young have been least affected in Sun-spots.

6. There is a great variation in the lines of this metal which are selected for widening by Sun-spots, either by different spots, or by the same spot on different days and at different appearances.

7. Excepting four out of the eleven titanium lines in this part of the spectrum, the rest are very much affected in spots both at the maximum and the minimum epochs.

8. The lines most persistently affected are among the faintest of the Fraunhofer lines, and among the brighter of the metallic lines.

9. A characteristic of some titanium lines is that they are very marked in the spectrum of the penumbra of spots.

10. Only three lines of this element have coincident chromospheric lines, and two of these are among the least widened of the lines.

11. Including "basic" lines, or lines with the dispersion used common to two elements, of twelve lines of calcium observed, six have coincident bright lines in the chromosphere. While "basic" lines of calcium, which are coincident with bright lines, have been recorded among the most widened lines, simple calcium lines having coincident chromospheric lines have not entered into this class.

12. In the minimum period the mean widening of calcium has increased, but the general variation is not at all great.

13. Sodium, represented by four lines, which include the D lines, was very much affected in the large spots of the maximum epoch.

14. Lines of barium, nickel, and manganese have never entered among the most widened lines.

15. The short lines in the metallic spectra of barium and nickel have been more widened than the long lines.

16. Eleven "basic" lines occur in this region. In a total of 407 observations, only fifteen times have such lines been recorded among the most widened lines, and twelve of these instances are due to lines which have calcium as one component. Their appearance among the more widened lines is about 31 per cent.

17. With regard to lines of unknown origin, the following conclusions have been derived from 2,088 individual observations:—

(*a*) About the maximum period a great number of faint lines not in Ångström are to be seen in Sun-spots.

(*b*) Such lines are not seen exclusively in maximum spots, but reappear in minimum spots when they are large—*e.g.* in the fine spot of June 1889, and to a less extent in that of May 6 of the same year.

(*c*) Some faint lines which have been persistently watched are to be seen greatly widened in every Sun-spot, large or small, whether in the disturbed or quiet period.

(*d*) The mean widening of all the five bright chromospheric lines coincident with unknown lines in this region has been low.

18. The C line is generally, though by no means always, less dark or unaffected over Sun-spots. When reversed, the reversal has been generally due to the faculæ between the spots.

19. Several lines marked as "telluric" in Ångström's map have been widened in Sun-spots.

20. Taking all the observations together, the lines in this region might provisionally be arranged as affected in Sun-spots in the following order:—Lines of unknown origin, faint lines of titanium, lines of calcium, sodium, iron, barium, nickel, and manganese.

On the Correction of Micrometric Measures for Refraction.

By Harold Jacoby, B.A.

(*Communicated by Dr. Gill.*)

The following investigation was undertaken in consequence of a suggestion made by Dr. David Gill, H.M. Astronomer at the Cape of Good Hope. Dr. Gill pointed out to me that the reduction of stellar parallax observations would be much facilitated if the refraction correction were expressed in terms of the true distance and position angle, and the formulæ carried to a degree of approximation high enough for the accurate correction of large distances.

Modern micrometers are capable of measuring much greater distances than could be managed with Bessel's heliometer; and it is therefore necessary to retain certain terms in the development of the refraction which were rejected by Bessel as insignificant. It is hoped, however, that their retention will entail but little additional labour upon the computer, and that the numerical work will be considerably lessened by the use of the tables which I have computed. These tables will also be found quite convenient for the correction of distance and position angle measures made with the ordinary equatoreal; for it will then be sufficient to use Table I. for the mean refraction, and to apply a correction, depending on the state of the meteorological instruments, easily derived from Table II. The method of doing this will be explained further on. It is, of course, needless to add that the tables are also adapted to the correction of stellar parallax or other measures made by the photographic method.

I shall first examine the corrections necessary for distance measures. If we assume the following notation:—

δ_0, ζ_0 = the means of the true declinations and zenith distances of the stars observed.

l_0, λ_0 = the apparent and true angles which the great circle joining the two stars makes with the vertical circle through the point midway between them.

s, σ = the apparent and true distances of the stars.

a^* = the usual Besselian quantity of vertical refraction.

a'' = the usual Besselian quantity for correcting micrometric measures for refraction.

p, π = the apparent and true position angles.

q = the true parallactic angle, corresponding to the zenith distance ζ_0.

ζ, ζ' = the true zenith distances of the two stars.

r, r' = the corresponding vertical refractions.

r_0 = the refraction corresponding to ζ_0.

we shall obtain, in a manner quite analogous to the method given by Chauvenet: †

$$l_0-\lambda_0=\frac{b-a}{b+a}\sin 2\lambda_0+\tfrac{1}{2}\left(\frac{b-a}{b+a}\right)^2\sin 4\lambda_0+\ldots. \qquad (1)$$

$$s-\sigma=-\sigma\left\{\frac{a-1}{a}+\frac{b-a}{ab}\cos^2\lambda_0-\frac{1}{2a}\left(\frac{b-a}{b+a}\right)^2\sin^2 2\lambda_0+\ldots.\right\} \qquad (2)$$

in which

$$a=\frac{\sin\zeta_0}{\sin(\zeta_0-r_0)} \qquad (3)$$

$$b=\frac{\zeta-\zeta'}{\zeta-\zeta'-(r-r')} \qquad (4)$$

Chauvenet, following Bessel, puts

$$r-r'=\frac{dr_0}{d\zeta_0}(\zeta-\zeta'),$$

and has, therefore, from (4)

$$b=\frac{1}{1-\dfrac{dr_0}{d\zeta_0}}.$$

But, in order to secure sufficient accuracy, it will be necessary to write:

$$r-r'=\frac{dr_0}{d\zeta_0}(\zeta-\zeta')+\tfrac{1}{2}\frac{d^2r_0}{d\zeta_0^2}(\zeta-\zeta')^2,$$

or, for brevity,

$$r-r'=\frac{dr_0}{d\zeta_0}(\zeta-\zeta')+n(\zeta-\zeta')^2,$$

and, consequently, in equation (4) the denominator will require a correction of

$$n(\zeta-\zeta')^2,$$

* See Chauvenet, *Spherical and Practical Astronomy*, vol. ii. Table II.

† *Spherical and Practical Astronomy*, vol. ii. p. 452. See also Engelmann, *Abhandlungen von F. W. Bessel*, vol. iii. p. 343.

and therefore b will require a correction of

$$+n(\zeta-\zeta'),$$

or, with sufficient accuracy,

$$+n\sigma\cos\lambda_0;$$

and since

$$\lambda_0=\pi-q$$

the correction required by b becomes

$$+n\sigma\cos(\pi-q).$$

This small correction required by Bessel's b will produce an appreciable effect on the refraction correction at large zenith distances. I shall disregard it for the present, but will show afterwards how it can be taken into account.

In the case of a no appreciable correction will be necessary on account of putting, as Bessel did,

$$r_0=\tfrac{1}{2}(r+r').$$

We shall have then, again following Chauvenet,

$$a=1+\alpha$$
$$b=1+\alpha+\alpha''\tan^2\zeta_0$$

and therefore, including terms of the second order,

$$\frac{a-1}{a}=\alpha(1-\alpha)$$
$$\frac{b-a}{ab}=\alpha''\tan^2\zeta_0(1-2\alpha-\alpha''\tan^2\zeta_0)$$
$$\frac{1}{2a}\left(\frac{b-a}{b+a}\right)^2=\tfrac{1}{8}\alpha''^2\tan^4\zeta_0,$$

which, substituted in equation (2), give:

$$s-\sigma=-\sigma[\alpha(1-\alpha)+\alpha''\tan^2\zeta_0\cos^2\lambda_0(1-2\alpha-\alpha''\tan^2\zeta_0)$$
$$-\tfrac{1}{8}\alpha''^2\tan^4\zeta_0\sin^2 2\lambda_0].$$

In the second term of this equation we can put α'' for α, since the error caused thereby is only

$$2\alpha''\tan^2\zeta_0\cos\lambda_0(\alpha-\alpha''),$$

which cannot exceed $0''{\cdot}003$ at 80° zenith distance.

And if we also put

$$k_1=\frac{\alpha''}{1+\alpha''\left(\frac{\alpha''}{1+\sec^2\zeta_0}\right)}=\alpha''[1-\alpha''(1+\sec^2\zeta_0)] \qquad (5)$$

we obtain:

$$s-\sigma=-\sigma[\alpha(1-\alpha)+k_1\tan^2\zeta_0\cos^2\lambda_0-\tfrac{1}{8}\alpha''^2\tan^4\zeta_0\sin^2 2\lambda_0] \qquad (5a)$$

Now let

$$M = k_1 \tan^2 \zeta_0 \cos^2 \lambda_0, \tag{6}$$

and we have

$$s - \sigma = -\sigma \left[\alpha(1-\alpha) + M - \tfrac{1}{2}\left(\frac{\alpha''}{k_1}\right)^2 M^2 \tan^2 \lambda_0\right]. \tag{7}$$

From the refraction tables we find:

Maximum value of α''	0·00026	Log 6·4158
„ „ α	0·00028	6·4487.

We may therefore neglect $\sigma\alpha^2$, whose maximum value for a distance of 8000″ is 0″·0006. Moreover, $\left(\frac{\alpha''}{k_1}\right)^2$ can never differ from unity by more than 0·017; and if we substitute unity for it, the error in the refraction for a distance of 8000″ cannot exceed 0″·0055. Making these indicated changes, and also putting

$$\lambda_0 = \pi - q,$$

equations (6) and (7) become

$$M = k_1 \tan^2 \zeta_0 \cos^2 (\pi - q) \tag{8}$$

$$s - \sigma = -\sigma \left[\alpha + M - \tfrac{1}{2} M^2 \tan^2 (\pi - q)\right]. \tag{9}$$

To return to the small correction required by b. We have, since

$$b - \alpha = \alpha'' \tan^2 \zeta_0,$$

the correction required by α'' equal to

$$\frac{\text{correction of } b}{\tan^2 \zeta_0},$$

or

$$\frac{n\sigma \cos (\pi - q)}{\tan^2 \zeta_0};$$

and from the usual Besselian formula,

$$s - \sigma = -\sigma\alpha'' \{\tan^2 \zeta_0 \cos^2 (p - q) + 1\},$$

we see that the correction required by $s - \sigma$ will be given with sufficient accuracy by

$$\text{correction} = -\frac{n\sigma^2 \cos (\pi - q)}{\tan^2 \zeta_0} [\tan^2 \zeta_0 \cos^2 (\pi - q) + 1]$$

$$= -n\sigma^2 [\cos^3 (\pi - q) + \cos (\pi - q) \cot^2 \zeta_0].$$

To obtain the value of n, we have:

$$r_0 = \alpha' \tan \zeta_0,$$

where α' is the usual quantity for vertical refraction, with the argument "true zenith distance." Differentiating this equation, we have:

$$\frac{dr_0}{d\zeta_0} = \alpha' \sec^2 \zeta_0 \sin 1' + \tan \zeta_0 \frac{d\alpha'}{d\zeta_0}, \tag{10}$$

by means of which a value of $\frac{dr_0}{d\zeta_0}$ may be computed for various zenith distances, the value of $\frac{da'}{d\zeta_0}$ being derived from the vertical refraction tables.

Now, in the equation

$$r-r=\frac{dr_0}{d\zeta_0}(\zeta-\zeta')+n(\zeta-\zeta')^2,$$

suppose

$$\zeta-\zeta'=7200'.$$

We shall then have

$$\zeta=\zeta_0+3600'$$
$$\zeta'=\zeta_0-3600'.$$

With these values of ζ and ζ' we can derive r and r' from the vertical refraction tables; and the value of $\frac{dr_0}{d\zeta_0}$ having just been obtained, we can compute n thus: *

$$n=\frac{r-r'-7200\frac{dr_0}{d\zeta_0}}{(7200)^2}.$$

The solution of the problem in hand is therefore contained in the following equations:

$$\left.\begin{aligned}
\frac{dr_0}{d\zeta_0}&=\alpha'\sec^2\zeta_0\sin 1''+\tan\zeta_0\frac{da'}{d\zeta_0}\\
n&=\frac{r-r'-(7200)\frac{dr_0}{d\zeta_0}}{(7200)^2}\\
k_1&=\frac{\alpha''}{1+\alpha''(1+\sec^2\zeta_0)}\\
M&=k_1\tan^2\zeta_0\cos^2(\pi-q)\\
A&=+\tfrac{1}{2}M^2\tan^2(\pi-q)\\
B&=+n[\cos^2(\pi-q)+\cos(\pi-q)\cot^2\zeta_0]\\
s-\sigma&=-\sigma(a+M)+A\sigma-B\sigma^2
\end{aligned}\right\}\qquad(11)$$

The quantity ζ_0 may generally be arrived at by a single computation, based on the mean hour angle (t_0) and the mean declination (δ_0) of the two stars observed. But the value of ζ_0

* This method has been employed in preference to the computation of $\frac{d^2r_0}{d\zeta_0^2}$ by a formula derived by differentiation from (10) in consequence of the difficulty of obtaining an accurate value of $\frac{d^2\alpha}{d\zeta_0^2}$ from the vertical refraction tables.

so obtained will not rigorously agree with the mean of the zenith distances of the two stars. A slight error may be introduced into the refraction at large zenith distances, unless ζ_0 be taken as the mean of the two zenith distances, separately computed. The following considerations show when it is sufficiently accurate to employ ζ_0 obtained from a single computation.

Since, in general,

$$\zeta = f(t, \delta)$$

$$\Delta\zeta = \left(\frac{d\zeta}{dt}\right)\Delta t + \tfrac{1}{2}\left(\frac{d^2\zeta}{dt^2}\right)\Delta t^2 + \ldots\ldots + \left(\frac{d\zeta}{d\delta}\right)\Delta\delta + \tfrac{1}{2}\left(\frac{d^2\zeta}{d\delta^2}\right)\Delta\delta^2 + \ldots\ldots \qquad (a)$$

But,

$$\left(\frac{d\zeta}{dt}\right) = \sin q \cos\delta \qquad \left(\frac{d^2\zeta}{dt^2}\right) = \frac{\cos\delta\cos\phi\cos A\cos q}{\sin\zeta}$$

$$\left(\frac{d\zeta}{d\delta}\right) = -\cos q \qquad \left(\frac{d^2\zeta}{d\delta^2}\right) = \sin^2 q\cot\zeta.$$

If we substitute these values in (a), and put

$$\Delta\zeta = \zeta - \zeta',$$

we easily get to terms of the second order inclusive:

$$\frac{\zeta+\zeta'}{2} = \zeta' + \tfrac{1}{2}\sin q_0\cos\delta_0(t-t') - \tfrac{1}{2}\cos q_0(\delta-\delta').$$

Now, if ζ_0 be the zenith distance corresponding to

$$t_0 = \tfrac{1}{2}(t+t'),$$

we can obtain from (a), by putting

$$\Delta\zeta = \zeta_0 - \zeta'$$

to terms of the second order inclusive:

$$\zeta_0 = \zeta' + \tfrac{1}{2}\sin q_0\cos\delta_0(t-t') - \tfrac{1}{2}\cos q_0(\delta-\delta') - \tfrac{1}{8}\frac{\cos\delta_0\cos q_0\cos A_0\cos\phi}{\sin\zeta_0}(t-t')^2 - \tfrac{1}{8}\sin^2 q_0\cot\zeta_0(\delta-\delta')^2.$$

So that we shall have the correction required by ζ_0:

$$d\zeta_0 = \frac{\zeta+\zeta'}{2} - \zeta_0 = \tfrac{1}{8}\frac{\cos\delta_0\cos q_0\cos A_0\cos\phi}{\sin\zeta_0}(t-t')^2 + \tfrac{1}{8}\cot\zeta_0\sin^2 q_0(\delta-\delta')^2,$$

and, therefore,

$$d(\tan^2\zeta_0) = \tfrac{1}{4}\sec^2\zeta_0\,[\sec\zeta_0\cos\delta_0\cos q_0\cos A_0\cos\phi\,(t-t')^2 + \sin^2 q_0(\delta-\delta')^2],$$

and finally,

$$d(\text{refraction}) = \tfrac{1}{4}\sigma k_1\cos^2(\pi-q)\sec^2\zeta_0\,[\sec\zeta_0\cos\delta_0\cos q_0\cos A_0\cos\phi\,(t-t')^2 + \sin^2 q_0(\delta-\delta')^2].$$

It would lead to complicated expressions if we were to determine the maximum of this expression. We shall, however, certainly exceed this maximum if we put

$$d\,(\text{refraction}) = \tfrac{1}{2}\,\sigma^2 k_1 \sec^2 \zeta_0\,(1+\sec\zeta_0)\sin^2 1'',$$

which amounts to $0''.01$

$$\text{for } \sigma = 4000'' \text{ when } \zeta_0 = 76°$$
$$,, \quad \sigma = 6000'' \quad ,, \quad \zeta_0 = 70°$$
$$,, \quad \sigma = 8000'' \quad ,, \quad \zeta_0 = 60°.$$

If, therefore, we observe very large distances far from the zenith, it will be advisable to compute ζ and ζ' separately, and employ

$$\zeta_0 = \tfrac{1}{2}(\zeta + \zeta').$$

The value of $s-\sigma$ given by equation (11) cannot theoretically be in error by $0''.01$, even when the zenith distance is 80° and σ as large as $8000''$. But equation (11) gives the refraction correction corresponding to a mean state of the barometer and thermometer. In order to get its value for the actual state of the atmosphere it is necessary to employ in place of α'', in equation (11), the quantity κ, whose value is taken from the vertical refraction tables by means of the usual formula:

$$\kappa = \alpha'' \beta^{\lambda''} \gamma^{\lambda''},$$

and instead of α, we must use

$$k = \alpha \beta^{\lambda} \gamma^{\lambda}.$$

But for all practical purposes I think it will be found quite sufficient to employ the tables which I have prepared. These tables are founded on the constants of the Pulkowa refractions, and the example afterwards given for comparison has been computed with the Pulkowa tables.* I shall now explain the method used in the construction of the tables.

In equation (11) it is clear that the small term $B\sigma^3$ will not require any meteorological correction. I shall neglect the meteorological correction of the term $A\sigma$, since from the last term of equation (5*a*) we see that the meteorological correction of $A\sigma$ can never exceed

$$0''.04\,\sigma\alpha''^2 \tan^4 \zeta_0,$$

or $0''.006$ at 75° zenith distance, and $0''.02$ at 80°.

There remains only the meteorological correction of the quantity

$$-\sigma\,(\alpha + M),$$

which quantity may be called the "mean refraction."

* O. Struve, *Tabulæ Refractionum in usum Speculæ Pulcovensis congestæ*, Petropoli, 1870.

It will be convenient to so arrange matters that the meteorological correction may be found by simply multiplying the quantity

$$-\sigma(a+M)$$

by a *meteorological factor*, to be taken from the tables, and adding the product to

$$-\sigma(a+M).$$

For this purpose let

f = the proper meteorological factor for k,

$f+x$ = the proper meteorological factor for a.

Then we shall have:

$$\text{Meteorological correction} = -\sigma(a+M)f-\sigma x a. \tag{12}$$

Now suppose that, in consequence of meteorological changes, k_1 becomes k_1+dk_1. It also becomes $k_1(1+f)$. Therefore

$$k_1+dk_1 = k_1(1+f),$$

or

$$f=\frac{dk_1}{k_1}. \tag{13}$$

Differentiating the third of equations (11) we get

$$\frac{dk_1}{da''}=\left(\frac{k_1}{a''}\right)^2,$$

which substituted in (13) gives:

$$f=\frac{k_1}{a''^2}da''.$$

But with the usual notation of the vertical refraction tables,

$$da''=a''(\beta^{A''}\gamma^{\lambda''}-1).$$

So that, finally,

$$f=\frac{k_1}{a''}(\beta^{A''}\gamma^{\lambda''}-1).$$

Similarly,

$$f+x=\beta^{A}\gamma^{\lambda}-1.$$

In both of these equations we shall produce no appreciable error if we write unity for A and A″. So we have

$$f=\frac{k_1}{a''}(\beta\gamma^{\lambda''}-1) \tag{14}$$

$$f+x=\beta\gamma^{\lambda}-1, \tag{15}$$

from which we easily obtain, by subtraction,

$$x=\frac{k_1}{a''}-1-\beta\gamma^{\lambda}\left(\frac{k_1}{a''}\gamma^{\lambda''-\lambda}-1\right)$$

I have neglected the last term of this equation. Its maximum effect on $s-\sigma$ cannot exceed 0″·004 at zenith distance 70°, and 0″·015 at 80°. We may therefore write

$$x=\frac{k_1}{a''}-1$$

and

$$-\sigma x a=-\sigma a\left(\frac{k_1}{a''}-1\right).$$

This equation gives us the value of the last term of equation (12), and it may be incorporated with the last of equations (11) without producing any appreciable error. To do this we introduce K, defined by

$$\mathrm{K}=a+a\left(\frac{k_1}{a''}-1\right)=k_1\frac{a}{a''},$$

and the last of equations (11) becomes

$$s-\sigma=-\sigma(\mathrm{K}+\mathrm{M})+\mathrm{A}\sigma-\mathrm{B}\sigma^2-\sigma(\mathrm{K}+\mathrm{M}) \qquad (16)$$

after we have added the meteorological correction.

In order to tabulate f I proceed as follows:—
Since λ'' can never differ much from unity, and since

$$f=f_{\lambda''=1}+\left(\frac{df}{d\lambda''}\right)_{\lambda''=1}(\lambda''-1),$$

we have from equation (14)

$$f=\frac{k_1}{a''}(\beta\gamma-1)+\frac{k_1}{\mu a''}\beta\gamma\log\gamma(\lambda''-1),$$

where μ is the modulus of the common system of logarithms; and if we put

$$f_0=\beta\gamma-1$$

$$\mathrm{Q}_0=\frac{k_1}{\mu a''}\log\gamma(\lambda''-1),$$

this equation becomes

$$f=\frac{k_1}{a''}f_0+\mathrm{Q}_0+f_0\mathrm{Q}_0. \qquad (17)$$

If we give to $\frac{k_1}{a''}$ the constant value 0·995, we shall produce the following maximum errors in the refraction:—

At 45°	zenith distance	0″·002
„ 60	„	0·004
„ 70	„	0·005
„ 80	„	0·025

We might tabulate f on the supposition that the indications of the attached and external thermometers are the same. But, if such is not the case, put

$t-T$ = excess of attached over external thermometer in Fahr. degrees.

y = the increase in $\log \beta$ per degree Fahr. $= -0{\cdot}0000386$,

then f will require the correction

$$df = 0{\cdot}995 \frac{y}{\mu} (f_0 + 1)(t-T),$$

or with sufficient accuracy,

$$df = -0{\cdot}000089\,(t-T),$$

so that (17) becomes

$$f = 0{\cdot}995\, f_0 + Q_0 + f_0 Q_0 - 0{\cdot}000089\,(t-T). \qquad (18)$$

It will be found convenient for computers to have f always positive. If R be the mean refraction, and f the meteorological factor, and if we put

ν = an auxiliary number,

we have

$$\nu R + \nu R \left(\frac{1}{\nu} f + \frac{1-\nu}{\nu} \right) = R(1+f) = \text{actual refraction}; \qquad (19)$$

which shows that we may substitute for f the quantity

$$\frac{1}{\nu} f + \frac{1-\nu}{\nu},$$

provided we substitute the quantity νR for R. Now, if we select ν such that

$$\nu < f + 1,$$

then

$$\frac{1}{\nu} f + \frac{1-\nu}{\nu} > 1.$$

For convenience in the computation of the tables I put

$$\nu = 0{\cdot}82916 \text{ and } \frac{1-\nu}{\nu} = 0{\cdot}20604.$$

Equation (18) then becomes

$$\text{Met. factor} = 1{\cdot}2\,(\beta\gamma - 1) + 0{\cdot}20604 + [0{\cdot}0814]\,Q_0 + [0{\cdot}0814]\,Q_0\,(\beta\gamma - 1) - 0{\cdot}0901\,(t-T), \qquad (20)$$

and the refraction, uncorrected for meteorological changes, will become, by (11) and (16),

$$\left.\begin{aligned} \nu M &= \nu k_1 \tan^2 \zeta_0 \cos^2 (\pi - q) \\ s - \sigma &= -\sigma\,(\nu K + \nu M) + A\sigma - B\sigma^2 \end{aligned}\right\} \qquad (21)$$

$$\text{Log } \nu K \text{ and log } \nu k,$$

may be taken from Table I. with the argument log $\tan^2 \zeta_0$.

$$1000\,A \text{ and } 1000000\,B$$

may be taken from Tables I. A. and I. B. They need only be multiplied by $\frac{\sigma}{1000}$ and $\left(\frac{\sigma}{1000}\right)^2$ to give the terms $A\sigma$ and $B\sigma^2$.

$$1{\cdot}2\,(\beta\gamma - 1) + 0{\cdot}20604$$

may be taken from Table II., with the arguments Barometer in English inches and Thermometer in Fahrenheit degrees.

$$[0{\cdot}0814]\,Q_0$$

may be taken from Table II. A. with the arguments log. $\tan^2 \zeta_0$ and "external thermometer." It is called the "first correction of the meteorological factor."

$$[0{\cdot}0814]\,Q_0\,(\beta\gamma - 1)$$

may be taken from Table II. B., using as arguments the quantities derived from Table II. and Table II. A.

$$-0{\cdot}0001\,(t - T)$$

may be taken, if desired, from Table II. C.

Although the tables are intended primarily for the computation of refractions when the *true* position angle and distance are known, they may also be used when we have only the observed distance and position angle. We can easily show that if we put

$$N = -\frac{s - \sigma}{\sigma},$$

then

$$\sigma - s = sN + \frac{s^2N^2}{s}$$

with an error that cannot exceed $0''{\cdot}002$ even at 80° zenith distance. But sN is the refraction computed by the tables, except that the apparent distance s has been used in place of the true distance σ. It is therefore evident that we can employ the apparent distance in computing the refraction, provided we apply to the result the correction

$$\frac{s^2N^2}{s}, \text{ or } \frac{[\text{Refraction}]^2}{\text{Distance}}.$$

This latter quantity has been tabulated, and may be taken from Table III. with the arguments apparent distance and refraction.

The position angle used should be the true position angle; so that if we wish to correct an observation of both position angle and distance, as in the case of a planet and comparison star, we would proceed as follows:—

I. Correct the observed position angle, which does not require a knowledge of the distance.

II. Compute the refraction in distance, using the true position angle from I. and the observed distance. Then add the correction from Table III.

If a series of stellar parallax observations are to be corrected for refraction in distance, it will be found convenient to arrange the work according to the following scheme. The same procedure is convenient whenever several measures of the same pair of stars are to be corrected.

I. Compute the true position angles and distances, using meridian observations of the principal star and the comparison stars. If meridian observations are not available, the true position angle and distance can be derived from one or two of the observations with sufficient accuracy.

II. Compute for every 10^m of hour angle, and for the mean declination of the two stars, the quantities q and $\tan^2 \zeta_0$, the computation being, of course, limited to hour angles corresponding to the observations. The quantities q and $\tan^2 \zeta$ can be tabulated once for all with the arguments declination and hour angle, and for the latitude of the observatory.

III. With the materials of I. and II. compute the mean refraction by equation (21) for every 10^m of hour angle, and tabulate it for every 10^m of sidereal time.*

IV. To obtain the proper refraction correction for any observation, enter the table computed under III. and take out the mean refraction. Take out the meteorological factor from the tables already explained (this factor will probably be constant for all the observations of a given night), and multiply the mean refraction by it. This gives the meteorological correction, which has only to be added to the mean refraction to get the actual refraction correction of the observation.

* If we are working at zenith distances large enough to make the terms $A\sigma$ and $B\sigma^2$ appreciable, this table should also give their sum. This sum should be placed in a separate column, as it does not need any meteorological correction. Log $\tan^2 \zeta_0$ should also be given, roughly, to serve as an argument for Table II. A.

I shall now take up the investigation of a formula for correcting position angles. If we substitute the values already given for a and b in equation (1) we have:

$$l_0 - \lambda_0 = \frac{a'' \tan^2 \zeta_0 \sin 2\lambda_0}{2(1+a) + a'' \tan^2 \zeta_0} + \frac{1}{2} \frac{a''^2 \tan^4 \zeta_0 \sin 4\lambda_0}{[2(1+a) + a'' \tan^2 \zeta_0]^2} + \ldots . \quad (22)$$

If we substitute a'' for a in this equation the error cannot exceed $0''{\cdot}2$ in $l_0 - \lambda_0$, and, if we omit the second term, we shall not introduce a greater error than $1''{\cdot}6$ at 80°, or $0''{\cdot}1$ at 70°. Making these changes, we find

$$l_0 - \lambda_0 = \frac{a'' \tan^2 \zeta_0 \sin 2\lambda_0}{2(1+a'') + a'' \tan^2 \zeta_0} = \frac{a'' \tan^2 \zeta_0 \sin 2\lambda_0}{2 + a''(1 + \sec^2 \zeta_0)},$$

which, by means of equation (5), becomes

$$l_0 - \lambda_0 = \frac{a''}{1 + \frac{a''}{k_1}} \tan^2 \zeta_0 \sin 2\lambda_0,$$

and if we give to $\frac{a''}{k_1}$ the constant value $1{\cdot}005$, we have

$$l_0 - \lambda_0 = [9{\cdot}69789]\, a'' \tan^2 \zeta_0 \sin 2\lambda_0 \quad (23)$$

with errors as follows:

At 80°	zenith distance	...	...	$1''{\cdot}6$
„ 70	„	...	...	$0''{\cdot}2$
„ 60	„	...	...	$0''{\cdot}6$
„ 50	„	...	...	$0''{\cdot}1$

If we let F be the meteorological factor for equation (23), we shall have

$$F = \beta\gamma\lambda'' - 1,$$

or by (14)

$$F = \frac{a''}{k_1} f;$$

and if we put

$$F = 1{\cdot}005 f \quad (24)$$

we shall only introduce the following insignificant errors in the refraction:

At 80°	zenith distance	...	...	$1''{\cdot}2$
„ 70	„	...	...	$0''{\cdot}2$
„ 60	„	...	...	$0''{\cdot}0$
„ 50	„	...	...	$0''{\cdot}1$

It will be convenient to arrange matters so as to use the same meteorological factor for position angles and distances. We shall then be able to derive it from the tables already given.

Now, if R be the refraction in position angle, and V and c two constants, we can use in place of F the quantity

$$\frac{1}{V}F + \frac{1-V}{V} + c,$$

provided we substitute $(1-c)\,V\,R$ for R.
For

$$(1-c)VR + (1-c)VR\left[\frac{1}{V}F + \frac{1-V}{V} + c\right] = RF + R - cVR\left[\frac{1}{V}F + \frac{1-V}{V} + c\right]$$

= actual refraction very nearly,

since the quantity

$$-cVR\left[\frac{1}{V}F + \frac{1-V}{V} + c\right]$$

only has the following maximum values:

At 80° zenith distance	...	...	3″·6
„ 70 „	...	...	0·8
„ 60 „	...	...	0·3

Now, if t be the tabular meteorological factor for distances, we have by (19) and (24)

$$t = \frac{1}{\nu}f + \frac{1-\nu}{\nu} = [0{\cdot}07919]\,F + 0{\cdot}20604,$$

so that if t is to be also our meteorological factor for position angles, we must have

$$\text{Log}\,\frac{1}{V} = 0{\cdot}07919 \qquad \frac{1-V}{V} + c = 0{\cdot}20604,$$

and, therefore,

$$\text{Log}\,V(1-c) = 9{\cdot}91819.$$

So that equation (23) becomes, after multiplying by cosec 1″ and introducing the term depending on the declination,*

$$p - \pi = [5{\cdot}23154]\,\alpha''\tan^2\zeta_0 \sin(\pi - q)\cos(\pi - q) + [5{\cdot}23262]\,k'\tan\zeta\sin q\tan\delta_0. \qquad (25)$$

Equation (25) may now be used with the meteorological factor from Table II., and the quantities $[5{\cdot}23154]\alpha''$ and $[5{\cdot}23262]k'$ can be taken from Table I. with the argument $\log\tan^2\zeta_0$.

It is to be remarked that the meteorological factors for the two terms of equation (25) are not strictly equal. They differ by the quantity

$$\frac{1}{V}\frac{\beta\gamma}{\mu}\log\gamma\,(\lambda' - \lambda''),$$

which cannot, however, influence the refraction appreciably,† and is neglected. Furthermore, equation (25) requires the use

* See Chauvenet, *Spherical and Practical Astronomy*, vol. ii. p. 457.

† Unless, of course, the declination be very great.

of the true position angle, π, in computing the refraction. We can, however, employ the observed position angle, p, without producing an error greater than

$$[5\cdot23154]\,\alpha''\,(\pi-p)\tan^2\zeta_0\cos 2\,(\pi-q)\sin 1'',$$

which will not in practice exceed $1''$ at 80° zenith distance.

I shall now give an example of the use of the tables. Suppose we have given

Barom. = 30·62 in. Therm. = 77° Fahrenheit

$\delta_0 = -20°\ 0'\ 0''$ $t_0 = 5^h\ 5^m$

$\pi = 164°\ 33'\ 36''$ $\sigma = 7200''$

$\phi = -33°\ 56'\ 3''\cdot2$

= latitude of Cape Observatory.

With these data we easily compute (or in the present case take from the manuscript tables of the Cape Observatory)

$\text{Log}\tan^2\zeta_0 = 0\cdot7828$ $q = 119°\ 33'\ 36''$.

So that

$$\pi - q = 45°\ 0'\ 0''.$$

The computation may now be arranged as follows:

For Distance.			For Met. Factor.		For Position Angle.		
Log σ	3·8573		Tab. II.	0·1770	Log $[5\cdot23]\alpha''$ (Tab. I.)	1·6659	
Log vK (Tab. I.)	6·3606		II. A.	−0·0015	Log $\tan^2\zeta_0$	0·7828	
Log σvK	0·2179	No. $1''\cdot651$	II. B.	0·0000	Log $\sin(\pi-q)$	9·8495	
			II. C.	0·0000	Log $\cos(\pi-q)$	9·8495	
Log vk_1 (Tab. I.)	6·3521		f	0·1755	Log 1st term	2·1477	
Log $\tan^2\zeta_0$	0·7828				1st term		$140''\cdot5$
Log $\cos^2(\pi-q)$	9·6990				Log $[5\cdot23]\,k'$ (Tab. I.)	1·6747	
Log vM	6·8339				Log $\tan\zeta_0$	0·3914	
Log σ	3·8573				Log $\sin q$	9·9394	
Log σvM	0·6912	No. $4''\cdot912$			Log $\tan\delta_0$	9·5611 n	
					Log 2nd term	1·5666 n	
Mean refraction		$+6''\cdot563$			2nd term		$-36''\cdot8$
$A\sigma$ (Tab. I. A)		0·000			Refraction		$103''\cdot7$
$+B\sigma^2$ (Tab. I. B)		+0·016			Met. cor. $(103\cdot7\times0\cdot1755)$		18·2
Met. corr. $(6\cdot56\times0\cdot1755)$		+1·152			Refraction		$121''\cdot9$
Refraction $(\sigma-s)$		$+7''\cdot731$				or	$2'\ 1''\cdot9$

It will be interesting to compare the results of the preceding example with a rigorous trigonometrical solution. From the given values of σ and π we deduce

$$\tfrac{1}{2}(\alpha'-\alpha) = 1019''\cdot887 \qquad \tfrac{1}{2}(\delta'-\delta) = -3470''\cdot106,$$

which, being applied to t_0 and δ_0, give for the two stars

$$t = 76^\circ\ 31'\ 59''\cdot887 \qquad \delta = -19^\circ\ 2'\ 9''\cdot894$$
$$t' = 75^\circ\ 58'\ 0''\cdot113 \qquad \delta' = -20^\circ\ 57'\ 50''\cdot106,$$

from which we get azimuths and zenith distances as follows:

$$A = 80^\circ\ 52'\ 18''\cdot13 \qquad \zeta = 68^\circ\ 36'\ 33''\cdot12$$
$$A' = 79^\circ\ 20'\ 42''\cdot94 \qquad \zeta' = 67^\circ\ 11'\ 42''\cdot13.$$

From the Pulkowa refraction tables we get by successive approximation, taking into account the barometric and thermometric conditions, the following refractions corresponding to ζ and ζ':

$$r = 142''\cdot050 \qquad r' = 132''\cdot500;$$

and, therefore, the following apparent zenith distances:

$$z = 68^\circ\ 34'\ 11''\cdot07 \qquad z' = 67^\circ\ 9'\ 29''\cdot63.$$

We can now solve the triangle formed by the zenith and the apparent places of the stars, and we obtain

$$s = 7192''\cdot252 \qquad p-q = 45^\circ\ 20'\ 20''\cdot79 \qquad p'-q' = 44^\circ\ 45'\ 49''\cdot91.$$

We also obtain, from the apparent zenith distances and azimuths, the apparent parallactic angles as follows:

$$q = 119^\circ\ 55'\ 36''\cdot35 \qquad q' = 119^\circ\ 9'\ 29''\cdot45,$$

which, being applied to the values of $p-q$ and $p'-q'$ immediately preceding, give the apparent position angles

$$p = 165^\circ\ 15'\ 57''\cdot14 \qquad p = 163^\circ\ 55'\ 19''\cdot36,$$

or the mean position angle

$$p = 164^\circ\ 35'\ 38''\cdot25.$$

Comparing these values of s and p with the values of σ and π originally assumed, we have

$$s-\sigma = -7''\cdot748 \qquad p-\pi = 2'\ 2'\cdot25.$$

Tables computed from the formulæ given in this paper have been separately printed. Copies may be obtained from the Royal Observatory, Cape of Good Hope.

Royal Observatory, Cape Town:
1890, *July.*

Note on Hind's Variable Nebula in Taurus. By S. W. Burnham.

Not long since I found a new double star in the vicinity of Hind's supposed variable nebula, and took occasion when the measures of the new pair were finished to examine the place of the nebula with the 36-inch refractor. The atmospheric conditions were always favourable. The distance of the components of the double star referred to is only 0″·16, and, therefore, it would have been useless to turn the telescope in that direction when the definition was inferior.

The nebula is easily found from the 8·7 mag. star, D.M. +19°, 704, which is 15ˢ *p* and 4′ *s*. The place of the nebula, as given by Dreyer, on the authority of D'Arrest, is identical with that of D.M. +19°, 706, the magnitude of which was estimated by Argelander as 9·4; and this is T *Tauri* of the variable star catalogues. On October 11 this star was estimated to be about 11·5 mag., but subsequent examinations indicated that it should be placed lower in the scale. I measured the difference in declination between this and the brighter star 15ˢ preceding; but finding the two stars could be connected directly by using the lowest micrometer eye-piece, the angle and distance were also measured on two nights. The measures in declination are as follows:—

1890·775	Diff. decl.	+243″·65
·777		243·40

The direct measures are:—

			Mag.	
1890·775	43°·5	336″·31	8·3	11·5
·777	43·8	336·07	8·4	12·5

This small star, if it is a star, is placed within a very small condensed nebula. It is somewhat elongated in the direction of 151°·7. A rough reading of the wires gave 4″·4 for the length of the nebula in this direction. It is less extended on the opposite side of the star or nucleus, with a shorter diameter of perhaps half that measured. It was examined with various powers, but it was impossible to say whether or not it had a disc like that of an ordinary star. If it were the bright nucleus of the small nebula, it would probably present the same stellar appearance. It will be noticed that this description of the nebula does not correspond with that in the early observations, where it was noted, when it was seen at all, as about 1′ in diameter.

On October 15 I asked Mr. Barnard to examine this region with the large telescope. His great experience in work of this kind, and remarkable acuteness of vision in detecting extremely faint, diffused objects, which would escape the ordinary observer, are well known. After careful attention he was able to see an excessively faint, round nebula, about $\frac{3}{4}'$ from the one previously described, in the estimated direction of 185°. This faint nebulosity was about 40″ or 50″ in diameter, and apparently not connected with the variable, and was of nearly the last degree of faintness for the light-power of the large instrument. It is, perhaps, too faint for any other telescope. I should not have seen it independently. Neither Mr. Barnard nor myself on any occasion could see the slightest trace of the OΣ nebula (seen also at times by D'Arrest, Tempel, and others, but invisible in the Rosse reflector), which should be 15ˢ preceding Hind's, nor any nebula in the immediate vicinity. Subsequently we looked at the small nebula with the 12-inch telescope, by way of getting a better estimate of its magnitude, and found that it was a very faint object, and in appearance precisely like any ordinary star of that magnitude. The nebulous surrounding was completely lost with the smaller instrument. I do not think it can be any brighter now than 12·5 mag. of the scale used in my double-star observations.

On the night of November 1 Mr. Keeler examined the nebula with the small spectroscope attached to the 36-inch telescope, and found that it was probably of the usual gaseous type, although on account of the extreme faintness of the nebula only the principal line at λ5005 was visible. The spectrum of the nucleus could not be seen.

Nothing seems to be definitely known of the period of this variable, T *Tauri*, and it seems to have been as much neglected as the nebula. It should be easy to determine, at least approximately, the extent and time of its change, and it is to be hoped that variable-star observers will give this object systematic attention. An instrument of moderate size will answer this purpose. It is probably now not far from its minimum brightness, in which case the variation must have a range of at least three magnitudes. A large aperture will be necessary to ascertain whether the small nebula, which is now visible immediately about the nucleus or star, is also subject to any change. I hope to be able to settle this question hereafter by making occasional examinations with the 36-inch refractor.

Lick Observatory:
1890, *November* 8.

New Nebulæ. By W. F. Denning.

The following nebulæ were discovered in *Camelopardus* while comet-seeking with a reflector of 10 inches aperture. With the exception of Nos. 1 and 10, they were first seen with a power of 60, field 50′. The positions may be regarded as correct within about 2′ or 3′, and they have been determined by comparison with small stars, which were kindly identified for me by Dr. Copeland, the Astronomer Royal for Scotland:—

No.	Date of Discovery.	Position for 1890. R.A.	N.P.D.	Description.
		h m s	° ′	
1	1889, Aug. 26	4 29 59	14 34·8	F.S, bM, * 12 Np.
2	1890, Nov. 7	4 40 19	11 52·1	F.S.R.
3	1890, Oct. 19	4 46 38	21 50·2	F.S.R., bMN, F dou. * Sf.
4	1890, Nov. 16	5 50 7	9 29·0	vF, S.
5	1890, Nov. 9	6 11 45	6 58·1	F.S.R, mbM.
6	1890, Oct. 17	6 59 26	4 15·0	vF, vvS, 12′ SSf, NGC 2300.
7	1890, Nov. 7	7 8 52	9 52·6	vF, pS, 22′ SSf, NGC 2336.
8	1890, Sept. 14	7 23 24	4 30·0	F.S.E., 46′ Sf, NGC 2300.
9	1890, Sept. 8	8 21 37	3 52·6	pF, S, mbM, * Nf.
10	1890, Aug. 23	8 34 30	4 5·6	F.S.R., gbM. In same field as preceding and Sff.

The place of No. 1 is probably very accurate, as it was given me by M. Charlois, of the Nice Observatory, who observed the nebula at my request.

Bristol: 1890, *November* 25.

Notes on Celestial Photographs taken at the Sydney Observatory. By H. C. Russell, B.A., F.R.S.

Since I sent you copies of some of my photographs of the Milky Way, &c., it has occurred to me that it was desirable that I should, with the same lens, &c., plate-development, and exposure, take a picture of some object well known to the members of the Royal Astronomical Society, so that there should be some measure of the work I have been doing upon southern objects. I therefore selected *Orion*, and upon an evening of average clearness I exposed a plate for four hours, and developed it as I did my other photographs. The glass positive and silver print from this which I have sent herewith will show better than any words what the photograph is like. Suffice it here to say that the

negative was much over-exposed, and shows folds of the nebula extending to the bright star ι. When developed, and before the intensifying solutions were applied, the negative was full of most beautiful detail of the central part of the nebula, but this, as will be seen, was all lost by intensifying the negative—in other words, treating it as my other negatives have been treated. The outer folds of the nebula shown here extend beyond those shown in any other photograph I have seen, but I have only seen some of the best. My photograph also shows some structure in the nebula about the third star in the Sword-handle, and if the effects here recorded are compared with those obtained with three hours' exposure on a good night upon η *Argûs*, it will afford a measure of the extreme faintness, photographically, of η *Argûs*.

I am also sending glass positive and silver-print reproductions from another negative of the *Nubecula Major*, obtained on October 17 with an exposure of 7 hours 3 minutes. This plate was taken upon the only available night since my previous letter, and brings out in a still more remarkable manner the spiral structure of this wonderful object, as well as two well-defined oval and spiral star clusters, the one about 3° north of the great one, the other south preceding it about the same distance. It is much to be regretted that the plate on which this negative was taken had several slight stains when developed; one occupies the whole of the preceding side of the plate, and can be traced past the preceding end of the great spiral; the others are small, faint, dark marks, extending across the plate and some distance from the centre.

Each increase in the time of exposure brings out new details of this striking object, all helping to indicate more and more clearly its spiral character. As seven hours is nearly the limit of darkness at this time of the year, I have placed the camera 18 miles out of the city, on a hill 615 feet high, and hope under a clearer atmosphere to secure a more perfect picture. I also send a print from a negative of *Nubecula Minor*, taken October 14 to 15, with eight hours' exposure, which brings out clearly the spiral character of this object, and its general similarity in form to the *Nubecula Major*.

Sydney Observatory:
1890, *November* 3.

Elements and Ephemeris of Zona's Comet.

By J. R. Hind, LL.D., F.R.S.

The following orbit depends upon an observation at Rome on November 16, one by Baron von Engelhardt on the 18th, and the Paris observations on the 21st :—

Perihelion passage, 1890, August 8·43592 G.M.T.

Longitude of perihelion	113° 16′ 52″·1	Appt. Eq. Nov. 20.
„ Ascending node	85 25 2·7	
Inclination	25 38 57·4	
Log perihelion distance	0·3138092	

Motion—retrograde.

The middle observation is thus represented $\Delta\lambda \cos\beta\,(c-o) = +0''\cdot3$, $\Delta\beta = +2''\cdot0$.

Ephemeris for Greenwich Midnight.

1890.	R.A. h m s	Decl. ° ′	Log Δ
Dec. 10	3 15 4	+33 57·7	0·2072
12	3 5 58	33 35·2	
14	2 57 26	33 11·1	0·2252
16	2 49 27	32 45·9	
18	2 42 0	32 19·9	0·2449
20	2 35 4	31 53·6	
22	2 28 38	31 27·4	0·2658
24	2 22 42	31 1·5	
26	2 17 14	+30 36·0	0·2872

The intensity of light on December 10 = 0·74, and on December 26 = 0·47, that on November 16 being taken as unity.

Ephemerides of the Satellites of Saturn, 1890–91.

By A. Marth.

(*Concluded.*)

Approximate Greenwich times of conjunctions of the satellites with the ends of the ring. In order to get the question settled whether the shadows of Tethys, Dione, and Rhea are discernible on the disc of *Saturn*, some of the times are added when the axes of the shadow-cones cross the central meridian.

1891.	h			h			h
May 16	8·8	Te. pn	May 22	8·6	Te. w	May 28	8·4 Te. ps
	10·6	Mi. pn		10·5	En. fs		10·8 Mi. fn
	11·5	Di. ps		12·2	Rh. w		14·5 En. pn
	15·6	En. ps		13·6	Mi. fs		15·4 Te. fs
	16·0	Mi. ps		16·4	Te. ps		16·7 Mi. pn
	16·1	Rh. fn	23	7·3	Te. e		19·1 Di. fn
	16·7	Te. w		7·7	Di. fn		19·3 Tit. inf. δ
17	7·5	Te. fs		10·8	Rh. ps		n. 17″
	7·8	Di. e		12·3	Mi. fs	29	1·0 Tit. Shadow
	9·0	En. fn		12·4	Di. Shadow		near north limb
	9·2	Mi. pn		13·0	En. ps		7·0 Te. fn
	14·6	Mi. ps		15·1	Te. fn		9·4 Mi. fn
	15·3	Te. e		15·5	Di. pn		11·1 Te. Shadow
	15·4	En. pn		17·7	Mi. fn		14·0 Te. pn
18	13·2	Mi. ps		19·1	Te. Shadow		15·3 Mi. pn
	14·0	Te. w	24	10·9	Mi. fs		15·4 Di. w
	16·6	Di. w		11·8	En. pn		17·0 En. fn
	17·9	En. fn		13·8	Te. ps	30	9·5 En. ps
19	7·3	Rh. fs		16·3	Mi. fn		11·5 Rh. Shadow
	10·3	En. ps		16·6	Di. ps		11·8 Di. fs
	11·9	Mi. ps		18·4	Rh. e		12·7 Te. fs
	12·6	Te. e	25	9·5	Mi. fs		13·9 Mi. pn
	13·0	Di. fs		12·4	Te. fn		14·5 Rh. pn
	16·7	En. fs		12·9	Di. e		15·8 En. fs
20	9·1	En. pn		14·3	En. fn	31	8·3 En. pn
	10·5	Mi. ps		14·9	Mi. fn		8·4 Te. Shadow
	11·3	Te. w		16·5	Te. Shadow		11·4 Te. pn
	14·0	Di. fn		17·0	Rh. fn		12·5 Mi. pn
	16·4	Mi. fs	26	6·1	Di. Shadow		12·8 Di. fn
	18·7	Di. Shadow		6·8	En. ps		13·1 Rh. w
21	2·4	Tit. sup. δ		8·1	Mi. fs		17·6 Di. Shadow
		s. 18″		9·2	Di. pn	June 1	9·1 Di. w
	8·1	Tit. close		11·1	Te. ps		10·0 Te. fs
		approach to		13·2	En. fs		10·8 En. fn
		shadow-cone		13·5	Mi. fn		11·2 Mi. pn
		of Saturn	27	9·7	Te. fn		11·7 Rh. ps
	9·1	Mi. ps		10·3	Di. ps		16·6 Mi. ps
	10·0	Te. e		12·1	Mi. fn		17·2 En. pn
	10·3	Di. w		13·8	Te. Shadow		17·9 Te. e
	10·5	Rh. Shadow		15·7	En. ps	2	8·7 Te. pn
	11·7	En. fn		16·7	Te. pn		9·6 En. fs
	13·6	Rh. pn	28	6·6	Di. e		9·8 Mi. pn
	15·0	Mi. fs		8·1	En. fn		15·2 Mi. ps
	17·8	Te. fn		8·3	Rh. fs		16·5 Te. w

1891.	h			h			h	
June	2 18·0	Di. e	June 8	8·5	Te. w	June 17	7·4	Rh. fn
	19·3	Rh. e		12·4	Rh. Shadow		11·3	Te. pn
	3 11·3	Di. Shadow		15·4	Rh. pn		13·4	Rh. Shadow
	12·1	En. ps		16·3	Te. ps		16·4	Rh. pn
	13·8	Mi. ps		17·9	Di. fn	18	7·9	Di. ps
	14·3	Di. pn	9	7·1	Te. e		9·9	Te. fs
	15·2	Te. e		14·1	Rh. w		15·0	Rh. w
	18·0	Rh. fn		14·3	Di. w		15·7	Di. fs
	4 10·9	En. pn		15·0	Te. fn	19	8·6	Te. pn
	12·4	Mi. ps	10	10·6	Di. fs		13·7	Rh. ps
	13·8	Te. w		12·7	Rh. ps		16·4	Te. w
	15·4	Di. ps		13·6	Te. ps		16·8	Di. fn
	5 11·0	Mi. ps	11	11·7	Di. fn	20	7·2	Te. fs
	11·7	Di. e		12·3	Te. fn		13·1	Di. w
	12·5	Te. e	12	8·0	Di. w		15·1	Te. e
	13·5	En. fn		10·9	Te. ps	22	1·0	Tit. sup. ♂ s. 15″
	6 1·5	Tit. sup. ♂ s. 16″	13	9·6	Te. fn		6·6	Tit. Middle of eclipse
	7·4	Tit. Middle of eclipse of uncertain duration		16·6	Te. pn	29	18·3	Tit. inf. ♂ n. 13″
				16·8	Di. e		23·5	Tit. Shadow
	8·0	Di. pn		18·6	Tit. inf ♂ n. 15″	July 8	0·9	Tit. sup. ♂ s. 13″
	9·2	Rh. fs	14	0·3	Tit. Shadow		5·9	Tit. Middle of eclipse
	9·7	Mi. ps		8·3	Te. ps	15	18·3	Tit. inf. ♂ n. 11″
	11·2	Te. w		13·2	Di. pn		22·2	Tit. Shadow
	12·3	En. fs		15·3	Te. fs			
	7 7·8	Rh. e	15	10·2	Rh. fs			
	9·1	Di. ps		13·9	Te pn			
	9·8	Te. e		14·2	Di. ps			
	16·9	Di. fs	16	8·8	Rh. e			
	17·6	Te fn		10·6	Di. e			
				12·6	Te. fs			

Approximate differences of right ascension and declination between Hyperion and the centre of Saturn.

Greenwich Noon.	α_1-A	δ_1-D		α_1-A	δ_1-D		α_1-A	δ_1-D
1891.	s	″		s	″		s	″
Jan. 7	−15·11	−22·9	Jan. 22	− 8·52	− 0·3	Feb. 6	+14·18	+19·6
8	12·47	−21·7	23	12·15	− 6·3	7	12·69	+21·8
9	8·89	−19·0	24	14·99	−11·9	8	9·73	+21·7
10	− 4·58	−14·7	25	−16·89	−16·8	9	5·74	+19·3
11	+ 0·14	− 9·1	26	17·74	−20·7	10	+ 1·20	+15·1
12	4·86	− 2·6	27	17·47	−23·4	11	− 3·45	+ 9·6
13	9·05	+ 4·3	28	16·08	−24·6	12	7·86	+ 3·4
14	+12·16	+10·7	29	−13·58	−24·3	13	11·72	− 3·1
15	13·76	+15·8	30	10·09	−22·2	14	14·80	− 9·5
16	13·62	+19·0	31	5·79	−18·3	15	−16·95	−15·4
17	+11·84	+19·9	Feb. 1	− 0·97	−12·8	16	18·03	−20·4
18	8·71	+18·7	2	+ 3·94	− 6·1	17	17·98	−24·2
19	4·69	+15·6	3	8·43	+ 1·3	18	16·78	−26·5
20	+ 0·21	+11·1	4	11·92	+ 8·7	19	−14·44	−27·1
21	− 4·33	+ 5·6	5	13·93	+15·0	20	11·06	−25·8

Greenwich Noon. 1891.	$\alpha_1 - A$ s	$\delta_1 - D$ ″		$\alpha_1 - A$ s	$\delta_1 - D$ ″		$\alpha_1 - A$ s	$\delta_1 - D$ ″
Feb. 21	− 6·82	−22·5	Mar. 25	− 1·73	+18·4	Apr. 26	− 4·78	−27·4
22	1·98	−17·3	26	6·28	+11·9	27	0·04	−21·4
23	+ 3·04	−10·5	27	10·37	+ 4·5	28	+ 4·69	−13·3
24	7·73	− 2·4	28	13·75	− 3·3	29	8·88	− 3·8
25	11·51	+ 5·9	29	−16·23	−11·0	30	11·99	+ 6·2
26	13·87	+13·7	30	17·69	−17·9	May 1	13·60	+15·4
27	+14·46	+19·8	31	18·04	−23·8	2	+13·49	+22·6
28	13·27	+23·6	Apr. 1	17·25	−28·3	3	11·76	+27·1
Mar. 1	10·51	+24·7	2	−15·32	−30·9	4	8·70	+28·5
2	6·63	+23·2	3	12·34	−31·4	5	4·76	+27·1
3	+ 2·10	+19·5	4	8·43	−29·6	6	+ 0·39	+23·1
4	− 2·62	+14·2	5	− 3·84	−25·4	7	− 3·98	+17·2
5	7·14	+ 7·7	6	+ 1·08	−18·8	8	8·09	+10·1
6	11·15	+ 0·6	7	5·88	−10·4	9	11·60	+ 2·2
7	14·37	− 6·5	8	10·00	− 0·7	10	14·33	− 5·7
8	−16·75	−13·4	9	12·88	+ 9·0	11	−16·16	−13·3
9	18·03	−19·5	10	+14·15	+17·7	12	16·97	−20·0
10	18·18	−24·4	11	13·63	+24·1	13	16·73	−25·5
11	17·17	−27·9	12	11·48	+27·8	14	15·42	−29·4
12	−15·08	−29·7	13	8·06	+28·3	15	−13·07	−31·1
13	11·80	−29·2	14	+ 3·84	+26·1	16	9·80	−30·6
14	7·68	−26·6	15	− 0·73	+21·5	17	5·77	−27·8
15	− 2·92	−21·8	16	5·24	+15·2	18	− 1·26	−22·5
16	+ 2·10	−15·0	17	9·34	+ 7·7	19	+ 3·34	−15·1
17	6·89	− 6·5	18	12·80	− 0·3	20	7·57	− 6·1
18	10·87	+ 2·7	19	−15·41	− 8·3	21	10·90	+ 3·5
19	13·52	+11·6	20	17·05	−15·8	22	12·85	+12·7
20	+14·45	+19·2	21	17·62	−22·3	23	+13·20	+20·2
21	13·57	+24·4	22	17·08	−27·4	24	11·94	+25·1
22	11·09	+26·9	23	−15·44	−30·8	25	9·31	+27·2
23	7·39	+26·5	24	12·56	−32·1	26	5·72	+26·4
24	+ 2·96	+23·5	25	9·12	−31·0	27	+ 1·61	+23·2

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

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Lieut.-General J. F. TENNANT, R.E., C.I.E., F.R.S., President, in the Chair.

Professor Bhuban Mohan Bandyopadhyay, B.A., F.R.Hist.S., Christian College, Lucknow, India;
Joseph Brooks, Trigonometrical Survey of New South Wales, Lands Department, Sydney;
James Stark Browne, 170 Sloane Street, S.W.;
Edward Tremlett Carter, Assoc. Inst. E. E., 29 Douglas Road, Willesden Lane, N.W.;
Rev. Aloysius L. Cortie, S.J., St. Beuno's College, St. Asaph, North Wales;
William Bladen Croft, M.A., 9 College Street, Winchester;
James Gallaher, The Limes, Leyton; and St. George's House, Eastcheap, E.C.;
Rev. H. Grattan Guinness, D.D., F.R.Hist.S., F.R.G.S., Harley House, Bow, E.; and Curbar, *viâ* Sheffield;
Charles W. H. Jeavons, Horseley Place, Tipton, Staffordshire;
John Mitchell, jun., Brockholes, Huddersfield;
William M. Pierson, San Francisco, California, U.S.A.;
James Lidderdale Scott, Shanghai, China;
Arthur Laidlaw Selby, M.A., University College of South Wales and Monmouthshire, Cardiff;
Rev. Walter Sidgreaves, S.J., Director of Stonyhurst College Observatory, Blackburn, Lancashire;
John Peter George Smith, Sweyney Cliff, Coalport, R.S.O., Shropshire;
Arthur John Walker, New College, Oxford; and Bayard's Lodge, Knaresborough, Yorkshire,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Thomas Richard Clapham, Gentleman, Austwick Hall, near Settle, Yorkshire (proposed by Herbert Sadler);

Arthur Kennedy, Solicitor, 1 Clement's Inn, W.C. (proposed by J. E. Drower).

Fifty-eight presents were announced as having been received since the last meeting, including, among others:

Annals of Harvard College Observatory, vol. xxiv (Results of Observations with the Meridian Photometer, 1882–86); presented by the Observatory.

Annalen der Sternwarte in Leiden, Band V. (containing Zone Observations 29° 50′ to 35° 10′); presented by the Observatory.

Collected Scientific Papers of James Clerk Maxwell, 2 vols.; presented by the Clerk Maxwell Memorial Committee.

MS. Observations of Shooting Stars, 1873–89, by W. F. Denning; presented by the Author.

Bichromate Battery and Ruhmkorff Coil, presented by Mr. J. E. H. Peyton.

Remarks on Mr. Fowler's Note on the Duplicity of α Lyræ.

By Professor H. C. Vogel, Foreign Associate.

In the last number of the *Monthly Notices* (vol. li. p. 8) Professor Lockyer communicated some photographic observations of stellar spectra made at South Kensington by Mr. Fowler, from which the duplicity of *α Lyræ* was concluded. Mr. Fowler would certainly have to be felicitated if at the very outset of his work on photographic spectra he had indeed succeeded in making a discovery of such great interest; but at present, for reasons which I beg to lay before the Society, it seems to me that his conclusions from his observations can scarcely be accepted without independent confirmation.

I think it will be of interest for me to communicate the results of photographic observations of *α Lyræ* made at Potsdam during the years 1888 to 1890.

These observations are:—

1. 1888, September 28.—Exp. 35^m. Many lines, definition very sharp, no trace of double lines.

2. 1888, November 11.—8^h 0^m, Potsdam mean time. Exp. 60^m. Beautiful photograph, a great number of lines, all lines very sharp; no duplication indicated.

3. 1888, November 13.—7^h 15^m, Potsdam mean time. Exp. 70^m. An extremely sharp photograph containing a great number of well-defined lines. No double lines.

4. 1889, May 31.—10^h 30^m, Potsdam mean time. Exp. 60^m. Good photograph, many lines, extremely sharp.

5. 1889, June 6.—10^h 15^m, Potsdam mean time. Exp. 30^m. Good photograph, many lines, extremely sharp.

6. 1889, September 15.—10^h 5^m, Potsdam mean time. Exp. 30^m. Good photograph, many lines, very sharp.

7. 1889, November 24.—6^h 40^m, Potsdam mean time. Exp. 30^m. Good photograph, sharp lines.

8. 1890, November 25.—5^h 58^m, Potsdam mean time. Exp. 45^m. Good photograph, only few lines visible, but very sharp.

9. 1890, November 25.—10^h 45^m, Potsdam mean time. Exp. 40^m. Photograph faint. Star near the horizon. Magnesium line (wave-length 448·14 $\mu\mu$) sharp and not doubled.

10. 1890, November 26.—8^h 43^m, Potsdam mean time. Exp. 45^m. Spectrum not very good on account of the low temperature. Nevertheless lines sufficiently sharp and certainly no trace of duplication.

Mr. Fowler deduces from his observations of *α Lyræ* a relative velocity of the component stars of about 370 miles per second, in a nearly circular orbit, with a period of about 24·68 hours. From these data it is easy to see that, during 23·83 hours, in every revolution of the stars in their orbit the lines must be separated by a distance corresponding to a relative motion of more than 20 miles. I state this as a lower limit, on the supposition that a separation of the lines cannot be seen when the relative motion is less than 20 miles; nevertheless, I am sure that the sharp definition of the lines in the photographs taken with the Potsdam spectrograph would permit a separation due to a very much smaller relative motion to be easily detected.

I beg to draw attention at first to the three Potsdam observations of 1890, which are in direct opposition to Mr. Fowler's results. Suggesting that if at one of these observations the lines were absolutely single, it is to be expected, accepting Mr. Fowler's period, that they would be separated in both the other observations; and especially in the second photograph taken on November 25, after an interval of five hours, nearly a maximum of separation must occur.

On Mr. Fowler's data it would rarely happen for the lines to be seen single, as Mr. Fowler himself points out: "The doubling of the line takes place so quickly that it is difficult to say when it is absolutely single." With a period of 24·68 hours, twice only during that interval for the very short time of 0·43 hours would the lines be narrow enough to appear single on the limit of separation suggested above—that is to say, at a distance corresponding to a relative motion not greater than 20 miles per second.

No calculation is needed to show how exceedingly small is the probability that all the Potsdam observations in 1888 and

1889 happened to be made precisely at the very times of these short minima. But there is another consideration which is even more crucial, arising from the great velocity with which the lines would begin to separate after the moments of complete coincidence. Now the average length of exposure given at Potsdam was 45 minutes. On Mr. Fowler's data, it is clear that it would have been absolutely impossible to have obtained the lines sharply defined with so prolonged an exposure. It is certain that the lines would have come out upon the plates very diffused through a breadth corresponding to a relative motion of about 50 miles; but, on the contrary, all the lines in the photographs of *α Lyræ* are well defined and sharply single.

In the Potsdam spectrograph a small part only of the spectrum is photographed in the neighbourhood of the Hγ-line, from about λ 420 $\mu\mu$ to λ 460 $\mu\mu$, and consequently the K-line, the duplicity of which Mr. Fowler observed, is not included in our photographs. Though Mr. Fowler says that other fine lines seen in his photographs were also "seen to be double in two or three photographs," yet possibly the objection might be raised that the spectra of the component stars of *α Lyræ* had only the hydrogen lines and K in common. The answer is that no relative displacement of the lines in the superposed spectra of the two component stars has occurred. A measurement of a group of the following lines on all the photographs: 446·88, 448·14 (magnesium-line), 452·30, 453·43, and 454·99 $\mu\mu$ showed no displacement greater than ± 5 miles.

Another objection might be urged in opposition to the evidence from the Potsdam photographs, based on the supposition that the fine lines in the part of the spectrum which they contain are all due to the spectrum of one only of the two component stars. This objection is completely met by the measures of the magnesium-line (448·14 $\mu\mu$) and of two lines near the Hγ-line (432·62 and 435·22 $\mu\mu$), which show that no displacement of any importance can be detected relatively to the terrestrial hydrogen-line simultaneously photographed on the plate. If Mr. Fowler's observations were correct, alterations in the positions of these fine lines, even if due to one component star only, should occur, corresponding to velocities up to 185 miles per second. Apart from the measures, which show that no such displacement took place, it is clear that, on this supposition of the motion of one star only showing on the plate, all the lines would be hazy and broad during an exposure prolonged through three-quarters of an hour.

I may add that all the lines in the part of the spectrum which is shown by the Potsdam photographs in the case of *β Aurigæ* are found to double periodically, and it is by no means difficult to measure the duplicity. On 1890, November 25, $9^h\ 43^m$ Potsdam mean time, I measured the separation of some lines in this star, which lines are also present in the spectrum of *α Lyræ*, and determined from them the relative motion of the two components forming the binary star *β Auriyæ*, as follows:—

W.L.	Miles.
448·14	136
449·16	128
450·15	127
453·43	133
454·99	134

I am sorry to have to say that the foregoing observations of *α Lyræ* made at Potsdam cannot be reconciled with Mr. Fowler's observations and the conclusions he draws from them.

It is not for me to suggest the possible causes which have led to the double lines which Mr. Fowler occasionally finds on his photographs of *α Lyræ*. Without great care and a special knowledge of the particular drawbacks to which the arrangement is liable, it is by no means unlikely for photographs taken with prisms over the object-glass to show occasionally a duplication or even a triplication of the lines in the spectrum of a star.

In the case of the Potsdam instrument, in which a slit is used, the possibility of getting double lines which are not due to real motions of the components of a close double star is practically excluded.

I hope Mr. Fowler will allow me to suggest to him to test his instrument and his method of working, by taking, in the first place, photographs of the spectrum of *β Aurigæ*, the motions of which are already known. Further, it would be well if he followed Professor Pickering's example in employing a greater dispersive power. The observations taken at Potsdam are with a dispersion still greater even than that used by Pickering.

I beg, in conclusion, to draw attention to the calculation and to the diagram given in Mr. Fowler's paper, as they fall far short of the accuracy which may be justly looked for in so important a statement. November 1, 8^h may be taken as the time of a zero point, because the following observations of this day show a regular increase in some way, and then calculation shows, with the given period of 24·68 hours, the following results:—

	h	Calculated Motion.	Observation.	C.—O.
Oct. 3	9·00	313 miles.	180 miles.	+133
8	8 00	314 „	370 „	− 56
9	7·00	204 „	232 „	− 28
10	7 33	176 „	260 „	− 84
11	8·50	215 „	218 „	− 3
12	8·25	139 „	294 „	−155
14	10·00	172 „	260 „	− 88
17	10·00	13 „	0 „	+ 13
27	8·00	282 „	109 „	+173
28	6·50	113 „	0 „	+113
Nov. 1	8·00	0 „	0 „	0
1	8·50	47 „	109 „	− 62
1	10·00	180 „	180 „	0
4	9·00	97 „	0 „	+ 97

An alteration of the zero point of ± half an hour, equal to about 50 miles, does not produce any remarkable improvement; and I doubt greatly whether, from a scientific point of view, any reasonable accordance between calculation and observation could in any way be made out.

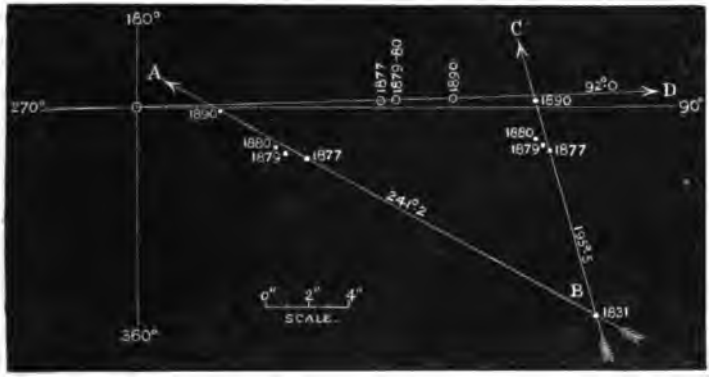
The Proper Motion of H 1968. By S. W. Burnham.

The double star *H* 1968 was first noted by Sir John Herschel with the 20-foot reflector at Slough, and entered in his Fifth Catalogue, published in 1833 (*Memoirs R.A.S.*, vol. vi.) The position-angle was measured and given as 61°·3, the distance being estimated as 20″±, and the magnitudes called 8 and 10–11. Naturally a pair of this class would not attract much attention, and, so far as I know, it was never looked at or referred to by anyone for nearly half a century following. During the several years in which I was using the 6-inch Clark telescope at Chicago, I looked up hundreds of double stars to fix their places by identifying them in some of the star catalogues, to correct various apparent errors in magnitudes, descriptions, &c., and for other purposes, and among others examined the pair in question in December 1875. The apparent change since Herschel's observation, particularly in distance, was very striking, and could not come from any ordinary error in the early description. I called the attention of Baron Dembowski to the probable change which had taken place, and he made a set of measures in 1876 and 1877, which will be found on page 347 of vol. i. of his observations. The name of the star is not given. Subsequently this pair was measured at Cincinnati, and still later by me with the 18½-inch refractor of the Dearborn Observatory. I have lately finished a series of measures at this observatory. So far as I know, these are all the measures that have been made anywhere. They are as follows:—

1831	61°·3	20″±	8	10–11	H	1*n*
1877·23	73·1	8·50	7·1	10·0	De	4*n*
1879·87	71·9	7·46	...	...	Cin	2*n*
1880·09	73·6	6·94	...	...	*β*	3*n*
1890·86	87·8	3·98	7·5	9 7	*β*	4*n*

These measures should be sufficient to determine the character of the motion. We have no means of ascertaining the exact time when Herschel measured the angle; but as he states the observations of the stars comprised in his Fifth Catalogue were made in the years 1830 and 1831, I have assumed 1831·0 as the most probable date, and that is near enough for the purposes of this investigation.

This star, according to Argelander, has a proper motion of 0″·356 in the direction of 92°·6; but it has been shown recently (Stumpe, Ast. Nach., No. 2999) that from an error in R.A. in one of the catalogues, this value is too large, and that the annual movement is 0″·252 in the position-angle of 92° 0. Laying down the measures given above, it is apparent that this proper motion entirely fails to account for the motion of the small star, which makes a large angle with the line of the motion of the principal component.



The accompanying diagram shows the several positions of the stars at the dates given. The original diagram was made on a scale of 2″ to one inch, and then photographed down to the size given here. The position-angles were accurately plotted to the tenth of a degree, and the distances to the second decimal place. The positions on the line A B are those of the small star, with the principal star considered fixed at the central point. If the smaller star were really fixed, then of course this line should be parallel with the line D, which is the direction of the proper motion of the other star. One of two things must certainly follow: either this proper motion is erroneous, or the smaller star has a proper motion of its own, for it is evident that no question of orbital motion can arise in this case. The apparent motion of B during the interval of 13·63 years between the measures of 1877 and 1890 is 4″·75, or at the rate of 0″·35 per annum, in the direction of 241°·2. Evidently, if this star is fixed, the proper motion of A given above is wrong, and should be 0″·35, in the direction of 61°·2. This would give some change in declination, instead of placing it substantially all in right ascension. It does not seem probable that so large an error exists in the recognised proper motion.

On the other hand, if the motion of A is sensibly correct, the real motion of B can be easily determined from the positions of that star on the line B C, which are plotted with reference to the

successive places of A along the line D at the several epochs, determined by the annual proper motion of 0″·252. In other words, these places are the actual positions in the heavens of the two stars at the several dates upon the assumption that the larger star has a yearly movement of 0″·252, in the direction of 92°·0. In that case B has an annual motion of 0″·18, in the direction of 195°·5. Both of the lines A and C are drawn through the positions given by the measures of 1877 and 1890, as they are made up of more individual observations, and will, I think, give a more reliable direction than could be derived from all the measures. In the inferences drawn from these measures no use is made of the approximate measures of Herschel, but we can see what the position-angle and distance should have been in 1831 by both assumptions of proper motion. At that time B must have been 24″ distant, in the direction of 65°·5, which is as close an agreement with Herschel's observation as could be expected. The minimum distance between the stars of 1″·8 will be reached about 1901, after which they will slowly separate.

The principal star is *Lalande* 593, and its place (1880) is :—

R. A. $0^h\ 21^m\ 35^s$
Decl. $-\ 17°\ 4'$

The magnitude is variously estimated. In addition to the magnitude given in connection with the measures, it is rated as 8 by Lalande and Gould, and 7·3 by Schönfeld.

Mount Hamilton.
1890 *Dec.* 5.

A Comparison between the Greenwich Lunar Observations, 1887, *and Hansen's Tables uncorrected and corrected for the Change in the Unit of Mean Time introduced in the Year* 1864, *and with Hansen's Tables as modified by Professor Newcomb.* By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

The Appendix to the *Monthly Notices*, vol. l., contains the results of an accurate comparison between the Greenwich Lunar Observations 1847–1861 and Hansen's Tables.

An examination of the residual errors H–O will show that the motion of the Moon was very closely represented by Hansen's Tables during the period 1847–1861. But the separate residuals indicate the existence of sensible, if small, errors in Hansen's Tables due either to defects of theory, or to imperfections in the practical methods of comparing the theoretical and observational results.

The largest residual errors H–O in longitude which I have noticed amongst the results from the meridional observations are :—

1852, Aug. 4 and 7	+ 6″·4	+ 7″·1
1854, Sept. 28 and 29	−13·2	−11·5

There are several negative residuals which are not much less than 10″, and several positive residual errors about 6″. But there are more than 80 of the negative residuals which are not less than 7″, and more than 40 of the positive residuals which are not less than 4″, and, speaking broadly, the residual errors in longitude may be considered to lie between

$$-7''\cdot5 \quad \text{and} \quad +4''\cdot5$$

The Greenwich Observations 1862–1863 were directly compared with Hansen's Tables, and the results are given in the Greenwich volumes of those years. As no fundamental changes were made in the methods adopted at Greenwich in comparing the tabular and observational results between the years 1847–1863, I have given the mean annual values of H–O in longitude for the years 1847–1863, both inclusive:—

1847.	1848.	1849.	1850.	1851.	1852.	1853.	1854.	1855
+0″·51	−0″·53	−1″·08	−0″·97	−1″·93	−1″·57	−2″·18	−2″·34	−1″·40

1856.	1857.	1858.	1859.	1860.	1861.	1862.	1863.
−1″·51	−2″·41	−2″·61	−2″·49	−3″·62	−2″·95	−2″·83	−1″·61

The mean error of Hansen's Tables for the period 1847–1863 was therefore

$$-1''\cdot854$$

If we apply this correction to the residual errors we obtain

1847.	1848.	1849.	1850.	1851.	1852.	1853.	1854.	1855.
+2″·36	+1″·32	+0″·77	+0″·88	−0″·08	+0″·28	−0″·33	−0″·49	+0″·45

1856.	1857.	1858.	1859.	1860.	1861.	1862.	1863.
+0″·34	−0″·56	−0″·76	−0″·64	−1″·77	−1″·10	−0″·98	+0″·24

These results show that the mean annual values of H–O are subject to small but sensible errors of a periodical character, besides the constant error −1″·85. And it might reasonably have been expected that the errors of Hansen's Tables for many subsequent years would be confined within similar limits to those which existed during the period 1847–1863, and that the mean annual residual errors would oscillate about the mean value −1″·85. But, instead of such being the case, the mean annual residual errors since 1864 have, without a single exception, been positive; and although the effects of small oscillations, of about the same magnitude as those shown during the period 1847–1863, can be clearly seen, they are completely

overshadowed by a regular secular change which has now made the mean annual residual errors of Hansen's Tables larger than the mean error from 1847 to 1863 by more than 18″.

As the Greenwich Lunar Observations have not recently been directly compared with Hansen's Tables, I have thought it desirable to compare them for the year 1887; but, for the purpose of showing the magnitude of the secular changes since the mean interval 1847–1863, and of drawing attention to the magnitude of the modifications of Hansen's Tabular Results, introduced by Professor Newcomb's corrections, and as corrected for the change of the variable, t, which I consider necessarily resulted from changes introduced in 1864, I have increased Hansen's residuals by the mean error 1″·85 which existed during the period 1847–1863.

This is absolutely necessary before comparing the effects of Professor Newcomb's corrections and mine. Professor Newcomb, from a direct discussion of recent observations after the change of the residual errors of Hansen's Tables had become well marked and recognised, altered the *epoch*, mean motion of the Moon relatively to the apse, and the long inequalities which enter into the fundamental argument of Hansen's Tables so that the mean residual error in longitude about 1875 became insensible; the rate of change per unit of time, agreed with the recent observations; and the earlier observations were approximately represented by an empirical modification of the long inequalities. But an alteration of t after 1864 to bring it back to its scale before 1864, if properly made, would simply leave the residual errors of Hansen's Tables after 1864 of the same magnitude and subject to the same periodical fluctuations as those which existed 1847–1863.

I may mention that I selected the year 1887 as the latest year available, but that I have recently received a copy of the Greenwich volume for 1888. I have examined the results sufficiently to say that, had this volume been available, a comparison between the residual errors as corrected by Professor Newcomb and those which directly result from my views of the alteration of t would have been slightly more favourable than the results here given. But practically the corrected results are sensibly identical, as they should be if the cause I have indicated is the real cause of the *per saltum* change in the errors of Hansen's Tables, for I, if my views are right, have altered back the new t to its former value; and Professor Newcomb, accepting the new t, alters the epoch and mean motion per unit of time to suit the variable t.

The Table of Errors of Longitude and E.N.P.D.

Day, 1887.		Errors of Longitude. Hansen *minus* Observed.			Errors of Ecliptic P.D. Hansen *minus* Observed.		
		Uncorrected for the Change of i made in 1864, but Corrected for the Mean Error of the Tables 1847 to 1863.	Corrected by Newcomb.	Corrected for the Change of i made in 1864, and for the Mean Error of the Tables 1847 to 1863.	Uncorrected for the Change of i made in 1864.	Corrected by Newcomb.	Corrected for the Change of i made in 1864.
		″	′	″	″	″	″
Jan.	1	+ 9·52	− 5·79	− 7·32	+ 5·37	+ 4·29	+ 4·13
	4	+ 15·60	− 1·06	− 2·31	+ 3·23	+ 2·75	+ 2·69
	5	+ 12·34	− 4·40	− 6·18	+ 1·50	+ 1·26	+ 1·29
	6	+ 14·71	− 2·84	− 4·36	− 1·61	− 1·40	− 1·37
	10	+ 17·19	− 1·73	− 3·67	− 1·94	− 0·42	− 0·18
	12	+ 19·95	+ 1·09	− 0·92	− 5·25	− 3·64	− 3·36
	16	+ 21·29	+ 3·50	+ 1·66	− 0·34	+ 0·08	+ 0·36
	30	+ 16·95	+ 1·20	− 0·11	+ 0·58	− 0·17	− 0·34
Feb.	1	+ 15·24	− 1·25	− 2·61	− 1·26	− 1·52	− 1·56
	4	+ 13·69	− 4·12	− 5·98	− 1·50	− 0·70	− 0·58
	6	+ 17·50	− 1·41	− 3·43	− 1·11	+ 0·25	+ 0·54
	7	+ 17·78	− 1·54	− 3·49	− 2·16	− 0·61	− 0·25
	15	+ 22·85	+ 5·60	+ 4·11	+ 2·18	+ 1·87	+ 1·80
	27	+ 14·93	− 1·16	− 2·29	+ 0·36	− 0·31	− 0·41
	28	+ 13·65	− 2·49	− 3·73	− 1·54	− 1·97	− 1·96
Mar.	1	+ 11·76	− 4·63	− 6·10	− 1·19	− 1·35	− 1·31
	2	+ 14·12	− 2·67	− 4·20	+ 0·99	+ 1·20	+ 1·29
	3	+ 14·78	− 2·43	− 4·02	− 2·96	− 2·28	− 2·31
	6	+ 13·79	− 5·27	− 7·04	− 2·51	− 1·01	− 0·73
	10	+ 22·10	+ 2·14	+ 0·31	− 2·04	− 0·74	− 0·54
	12	+ 19·46	+ 0·56	− 1·46	− 2·14	− 1·58	− 1·49
	13	+ 23·16	+ 4·71	+ 2·94	+ 0·55	+ 0·68	+ 0·71
	16	+ 21·30	+ 4·55	+ 3·00	− 3·58	− 4·27	− 4·57
Apr.	2	+ 14·40	− 3·50	− 5·36	+ 0·18	+ 1·40	+ 1·74
	3	+ 14·04	− 4·27	− 6·26	− 2·11	− 0·69	− 0·41
	4	+ 14·86	− 4·52	− 6·14	− 1·98	− 0·41	− 0·08
	7	+ 18·30	− 1·48	− 3·61	− 3·47	− 2·36	− 2·14
	8	+ 19·59	+ 0·20	− 2·04	− 2·34	− 1·6	− 1·47
	10	+ 21·11	+ 2·54	+ 0·64	− 2·11	− 2·07	− 2·25
	11	+ 22·77	+ 4·57	+ 2·96	+ 2·87	+ 2·37	+ 2·32

Day, 1887.		Errors of Longitude. Hansen *minus* Observed.			Errors of Ecliptic P.D. Hansen *minus* Observed.		
		Uncorrected for the Change of *t* made in 1864, but corrected for the Mean Error of the Tables 1847 to 1863.	Corrected by Newcomb.	Corrected for the Change of *t* made in 1864, and for the Mean Error of the Tables 1847 to 1863.	Uncorrected for the Change of *t* made in 1864.	Corrected by Newcomb.	Corrected for the Change of *t* made in 1864.
		″	″	″	″	″	″
May	3	+14·07	−5·29	−7·02	−1·47	−0·21	+0·18
	5	+17·94	−1·69	−3·61	−0·54	+0·22	+0·48
	7	+18·97	−0·38	−2·16	−2·71	−2·68	−2·69
	8	+18·89	−0·20	−1·73	−1·93	−2·19	−2·35
	9	+20·08	+1·67	+0·08	−0·28	−0·80	−1·11
	12	+20·79	+4·03	+2·74	+1·46	+0·36	−0·04
	14	+21·15	+4·99	+3·88	+1·91	+0·46	+0·41
	26	+15·62	−2·10	−3·77	−3·74	−2·77	−2·32
	30	+13·97	−4·74	−6·51	−0·38	+1·01	+1·26
	31	+15·34	−3·30	−5·50	−2·52	−1·56	−1·07
June	5	+18·42	−0·15	−1·94	−1·09	−1·43	−1·83
	6	+20·00	+1·70	+0·15	+0·24	−0·84	−0·84
	8	+19·61	+2·49	+0·90	+3·40	+2·09	+1·85
	9	+20·66	+3·94	+2·44	+1·09	−0·22	−0·52
	11	+20·01	+4·16	+2·67	+3·06	+1·92	+1·53
	12	+17·16	+1·04	−0·09	+2·12	+0·97	+0·73
	13	+20·87	+4·96	+3·67	+1·12	+0·27	−0·04
	14	+17·28	+1·29	+0·05	+2·09	+1·20	+1·18
	25	+19·07	+0·62	−1·29	−6·54	−5·07	−4·70
	30	+16·56	−1·87	−4·07	−1·24	−0·98	−0·95
July	1	+18·88	+0·36	−1·59	−1·65	−1·60	−1·78
	2	+19·95	+1·89	−0·23	−0·64	−1·03	−1·28
	3	+19·63	+1·52	−0·21	−0·56	−1·16	−1·53
	5	+18·23	+0·95	−0·74	−1·13	−2·39	−2·63
	7	+19·58	+2·97	+1·42	+0·64	−0·71	−1·01
	10	+20·59	+4·50	+3·33	+0·86	−0·20	−0·40
	11	+18·10	+2·24	+0·82	+1·83	+0·89	+0·86
	12	+20·84	+4·67	+3·49	+1·53	+0·88	+0·74
	26	+16·22	−2·58	−4·62	−0·48	+0·02	+0·41
	27	+14·42	−4·18	−6·21	−0·99	−0·72	−0·56
	28	+18·88	+0·60	−1·36	−4·54	−4·60	−4·64
	29	+19·25	+1·18	−0·68	−1·30	−1·61	−1·81

		Errors of Longitude. Hansen *minus* Observed.			Errors of Ecliptic P.D. Hansen *minus* Observed.		
Day, 1887.		Uncorrected for the Change of t made in 1864, but corrected for the Mean Error of the Tables 1847 to 1863.	Corrected by Newcomb.	Corrected for the Change of t made in 1864, and for the Mean Error of the Tables 1847 to 1863.	Uncorrected for the Change of t made in 1864.	Corrected by Newcomb.	Corrected for the Change of t made in 1864.
		″	″	″	″	″	″
July	30	+20·39	+2·63	+0·75	−0·42	−1·16	−1·31
	31	+21·07	+3·51	+1·83	+2·18	+1·32	+0·98
Aug.	2	+19·68	+2·41	+1·10	+0·33	−1·04	−1·27
	3	+19·87	+3·21	+1·61	+1·98	+0·82	+0·29
	4	+19·91	+3·28	+1·91	+1·09	−0·50	−0·59
	5	+20·64	+4·29	+2·93	−0·31	−1·53	−1·87
	6	+17·84	+1·58	+0·40	+2·07	+1·23	+0·72
	7	+17·07	+1·42	−0·31	+3·10	+2·39	+1·96
	8	+19·50	+3·78	+2·29	+1·76	+1·09	+0·89
	23	+17·37	−1·45	−3·89	+1·11	+1·69	+1·70
	24	+20·21	+1·23	−0·53	−1·89	−2·08	−1·83
	25	+18·87	+0·46	−1·35	+1·37	+0·79	+1·01
	31	+19·71	+2·97	+1·74	+0·62	−0·63	−1·02
Sept.	2	+20·94	+4·62	+3·43	+1·12	+0·16	−0·30
,,	6	+21·29	+5·23	+3·91	+0·79	+0·39	+0·43
	7	+17·27	+1·03	−0·34	+2·32	+2·27	+2·29
	8	+19·09	+2·63	+1·21	−0·09	+0·20	+0·23
	28	+20·21	+3·68	+2·49	+2·36	+1·03	+0·80
	29	+19·16	+3·22	+1·60	+3·17	+1·54	+1·74
Oct.	1	+18·27	+2·21	+0·82	+2·61	+1·73	+1·63
	2	+17·59	+1·81	+0·20	+1·19	+0·73	+0·45
	10	+19·22	+1·19	−0·52	−0·54	+0·75	+1·13
	22	+19·72	+1·95	+0·15	−0·74	−1·92	−2·30
	24	+20·31	+3·55	+2·03	+1·00	−0·34	−0·62
	25	+20·10	+3·69	+2·23	+2·66	+1·38	+1·07
	28	+18·93	+2·70	+1·49	+1·84	+0·96	+0·84
	30	+17·64	+1·55	+0·04	+1·46	+0·97	+0·97
	31	+17·42	+1·18	−0·17	−0·82	−0·73	−0·96
Nov.	1	+19·98	+3·28	+2·22	−0·43	−0·40	−0·25
	4	+17·67	+0·71	−0·69	−1·80	−0·71	−0·69
	5	+15·56	−1·41	−3·08	−1·27	+0·01	+0·12
	25	+17·60	+1·47	+0·09	+3·01	+2·32	+2·20

Day, 1887.		Errors of Longitude. Hansen *minus* Observed.			Errors of Ecliptic P.D. Hansen *minus* Observed.		
		Uncorrected for the Change of l made in 1864, but corrected for the Mean Error of the Tables 1847 to 1863.	Corrected by Newcomb.	Corrected for the Change of l made in 1864, and for the Mean Error of the Tables 1847 to 1863.	Uncorrected for the Change of l made in 1864.	Corrected by Newcomb.	Corrected for the Change of l made in 1864.
		″	″	″	″	″	″
May	3	+14·07	−5·29	−7·02	−1·47	−0·21	+0·18
	5	+17·94	−1·69	−3·61	−0·54	+0·22	+0·48
	7	+18·97	−0·38	−2·16	−2·71	−2·68	−2·69
	8	+18·89	−0·20	−1·73	−1·93	−2·19	−2·35
	9	+20·08	+1·67	+0·08	−0·28	−0·80	−1·11
	12	+20·79	+4·03	+2·74	+1·46	+0·36	−0·04
	14	+21·15	+4·99	+3·88	+1·91	+0·46	+0·41
	26	+15·62	−2·10	−3·77	−3·74	−2·77	−2·32
	30	+13·97	−4·74	−6·51	−0·38	+1·01	+1·26
	31	+15·34	−3·30	−5·50	−2·52	−1·56	−1·07
June	5	+18·42	−0·15	−1·94	−1·09	−1·43	−1·83
	6	+20·00	+1·70	+0·15	+0·24	−0·84	−0·84
	8	+19·61	+2·49	+0·90	+3·40	+2·09	+1·85
	9	+20·66	+3·94	+2·44	+1·09	−0·22	−0·52
	11	+20·01	+4·16	+2·67	+3·06	+1·92	+1·53
	12	+17·16	+1·04	−0·09	+2·12	+0·97	+0·73
	13	+20·87	+4·96	+3·67	+1·12	+0·27	−0·04
	14	+17·28	+1·29	+0·05	+2·09	+1·20	+1·18
	25	+19·07	+0·62	−1·29	−6·54	−5·07	−4·70
	30	+16·56	−1·87	−4·07	−1·24	−0·98	−0·95
July	1	+18·88	+0·36	−1·59	−1·65	−1·60	−1·78
	2	+19·95	+1·89	−0·23	−0·64	−1·03	−1·28
	3	+19·63	+1·52	−0·21	−0·56	−1·16	−1·53
	5	+18·23	+0·95	−0·74	−1·13	−2·39	−2·63
	7	+19·58	+2·97	+1·42	+0·64	−0·71	−1·01
	10	+20·59	+4·50	+3·33	+0·86	−0·20	−0·40
	11	+18·10	+2·24	+0·82	+1·83	+0·89	+0·86
	12	+20·84	+4·67	+3·49	+1·53	+0·88	+0·74
	26	+16·22	−2·58	−4·62	−0·48	+0·02	+0·41
	27	+14·42	−4·18	−6·21	−0·99	−0·72	−0·56
	28	+18·88	+0·60	−1·36	−4·54	−4·60	−4·64
	29	+19·25	+1·18	−0·68	−1·30	−1·61	−1·81

Day, 1887.	Errors of Longitude. Hansen *minus* Observed. Uncorrected for the Change of t made in 1864, but corrected for the Mean Error of the Tables 1847 to 1863.	Corrected by Newcomb.	Corrected for the Change of t made in 1864, and for the Mean Error of the Tables 1847 to 1863.	Errors of Ecliptic P.D. Hansen *minus* Observed. Uncorrected for the Change of t made in 1864.	Corrected by Newcomb.	Corrected for the Change of t made in 1864.
July 30	+20″·39	+2″·63	+0″·75	−0″·42	−1″·16	−1″·31
31	+21·07	+3·51	+1·83	+2·18	+1·32	+0·98
Aug. 2	+19·68	+2·41	+1·10	+0·33	−1·04	−1·27
3	+19·87	+3·21	+1·61	+1·98	+0·82	+0·29
4	+19·91	+3·28	+1·91	+1·09	−0·50	−0·59
5	+20·64	+4·29	+2·93	−0·31	−1·53	−1·87
6	+17·84	+1·58	+0·40	+2·07	+1·23	+0·72
7	+17·07	+1·42	−0·31	+3·10	+2·39	+1·96
8	+19·50	+3·78	+2·29	+1·76	+1·09	+0·89
23	+17·37	−1·45	−3·89	+1·11	+1·69	+1·70
24	+20·21	+1·23	−0·53	−1·89	−2·08	−1·83
25	+18·87	+0·46	−1·35	+1·37	+0·79	+1·01
31	+19·71	+2·97	+1·74	+0·62	−0·63	−1·02
Sept. 2	+20·94	+4·62	+3·43	+1·12	+0·16	−0·30
.. 6	+21·29	+5·23	+3·91	+0·79	+0·39	+0·43
7	+17·27	+1·03	−0·34	+2·32	+2·27	+2·29
8	+19·09	+2·63	+1·21	−0·09	+0·20	+0·23
28	+20·21	+3·68	+2·49	+2·36	+1·03	+0·80
29	+19·16	+3·22	+1·60	+3·17	+1·54	+1·74
Oct. 1	+18·27	+2·21	+0·82	+2·61	+1·73	+1·63
2	+17·59	+1·81	+0·20	+1·19	+0·73	+0·45
10	+19·22	+1·19	−0·52	−0·54	+0·75	+1·13
22	+19·72	+1·95	+0·15	−0·74	−1·92	−2·30
24	+20·31	+3·55	+2·03	+1·00	−0·34	−0·62
25	+20·10	+3·69	+2·23	+2·66	+1·38	+1·07
28	+18·93	+2·70	+1·49	+1·84	+0·96	+0·84
30	+17·64	+1·55	+0·04	+1·46	+0·97	+0·97
31	+17·42	+1·18	−0·17	−0·82	−0·73	−0·96
Nov. 1	+19·98	+3·28	+2·22	−0·43	−0·40	−0·25
4	+17·67	+0·71	−0·69	−1·80	−0·71	−0·69
5	+15·56	−1·41	−3·08	−1·27	+0·01	+0·12
25	+17·60	+1·47	+0·09	+3·01	+2·32	+2·20

Day, 1887.	Errors of Longitude. Hansen *minus* Observed. Uncorrected for the Change of *t* made in 1864, but corrected for the Mean Error of the Tables 1847 to 1863.	Errors of Longitude. Hansen *minus* Observed. Corrected by Newcomb.	Errors of Longitude. Hansen *minus* Observed. Corrected for the Change of *t* made in 1864, and for the Mean Error of the Tables 1847 to 1863.	Errors of Ecliptic P.D. Hansen *minus* Observed. Uncorrected for the Change of *t* made in 1864.	Errors of Ecliptic P.D. Hansen *minus* Observed. Corrected by Newcomb.	Errors of Ecliptic P.D. Hansen *minus* Observed. Corrected for the Change of *t* made in 1864.
	″	″	″	″	″	″
Nov. 27	+17·92	+1·73	+0·17	+0·96	+0·91	+0·75
29	+17·14	+0·54	−0·90	−0·83	−0·44	−0·29
30	+16·65	−0·10	−1·77	−0·77	−0·36	+0·09
Dec. 5	+18·94	+0·95	−0·86	−3·52	−2·17	−1·75
6	+14·99	−3·33	−5·16	−3·48	−2·06	−1·81
8	+20·49	+1·15	−0·64	−3·53	−2·63	−2·34
26	+15·63	−1·15	−2·50	−1·68	−1·45	−1·27
27	+17·31	+0·34	−1·03	−1·85	−1·19	−1·10
31	+17·95	+0·02	−1·84	−2·09	−0·58	−0·28
Sums, without regard to signs	**1866″·88**	**254″·11**	**249″·44**	**182″·24**	**134″·93**	**132″·05**
Means, without regard to signs	**18″·13**	**2″·47**	**2″·42**	**1″·77**	**1″·31**	**1″·28**
Mean Errors for the year	**+18″·13**	**+0″·71**	**−0″·91**	...	...	...

Radcliffe Observatory, Oxford:
1891 *January* 8.

Photographic Evidence of Variability in the Nucleus of the Great Nebula in Andromeda. By Isaac Roberts, F.R.S.

The photographic evidence of variability in the nucleus of the great nebula in *Andromeda* will best be appreciated if I give in chronological order the dates when the photographs were taken, and describe the appearance of the nucleus on each plate.

On August 30, 1885, a plate was exposed during 30 minutes, when the nucleus did not appear to be distinctly stellar. The Nova was then near, and was much brighter than the nucleus. The star images on the plate, including that of the Nova, are elongated because of bad clock driving, but the nucleus does not show elongation, though stars which were as faint as the nucleus are elongated.

On October 24, 1886, a plate was exposed during 73 minutes, and it shows a faint stellar nucleus, which is elongated and two centred, like all the stars on the plate.

On October 10, 1887, a plate was exposed during 3 hours, which shows the nucleus very faintly stellar, and it is elongated like all the stars on the plate. The rings surrounding the nebula are visible on this plate, but I did not obtain full evidence of their true character until the end of 1888.

On November 15, 1887, a plate was exposed during 2 hours and 35 minutes, but no trace of a stellar nucleus can be detected. The stars on the plate are elongated, but there is no elongation of the nucleus. There is a faint trace of the rings visible.

On October 1, 1888, a plate was exposed during 2 hours, but there is no stellar nucleus visible. The rings are strongly shown.

On October 2, 1888, a plate was exposed during 2 hours and 32 minutes, but the nucleus is not stellar. The rings are strongly shown.

On December 29, 1888, a plate was exposed during 4 hours, on which the rings are strongly shown, but there is no stellar nucleus.

On October 12, 1890, a plate was exposed during 3 hours and 5 minutes, but the nucleus is not stellar.

On November 1, 1890, a plate was exposed during 15 minutes, and the nucleus is distinctly stellar. Its stellar character is more strongly shown on this negative than on the others where it is visible.

On December 9, 1890, a plate was exposed during 15 minutes, and also another immediately following it, with an exposure of 5 minutes, and a stellar nucleus is very strongly shown on both plates. On another plate, which was exposed on the same night during one hour, the stellar nucleus is strongly visible through the nebulosity.

From the evidence given above we may reasonably infer that the nucleus of the nebula is variable, and that it will be practicable to study the character of the variability without the necessity of giving long exposures of the plates.

Summary of the evidence given above:—

1885 August 30. Exposure 30 minutes. No stellar nucleus.

1886 October 24. Exposure 73 minutes. Faint stellar nucleus.

1887 October 10. Exposure 3 hours. Very faint stellar nucleus.

1887 November 15. Exposure 2 hours and 35 minutes. No trace of a stellar nucleus.

1888 October 1. Exposure 2 hours. No stellar nucleus.

1888 October 2. Exposure 2 hours and 32 minutes. No stellar nucleus.

1888 December 29. Exposure 4 hours. No stellar nucleus.

1890 October 12. Exposure 3 hours and 5 minutes. No stellar nucleus.

1890 November 1. Exposure 15 minutes. The nucleus is very strongly stellar.

1890 December 9. Exposures 5, 15, and 60 minutes respectively. The nucleus is strongly stellar on each plate.

Isaac Roberts' New Observatory on Crowborough Hill, Sussex.
By Isaac Roberts, F.R.S.

The observatory is placed on the summit of Crowborough Hill, in Sussex, which is one of the highest points in the South of England, and commands the horizon around without material obstruction. The floor of the observatory is 780 feet 7 inches above sea-level. The whole of the buildings are erected on a level platform of concrete, the top of which is about four feet above the ground, which slopes towards the south-east. The buildings are one story in height, and the floors are raised fifteen inches above the platform or terrace, and are on one uniform level throughout. The limit to one story in height permits the telescopes to be brought down to within twenty degrees of the horizon when pointed over the roof of the house. The observatory is placed due south, and is 20 feet square inside, with a transit room opening from it on the west side. Adjoining the observatory on the north side is a physical laboratory and a chemical laboratory, with dark room and photo-enlarging arrangements. These and the observatory are connected with the dwelling-house by a corridor, on one side of which is a mechanic's shop, heating-chamber, and library. At the end of the corridor is the dwelling-house. The dome of the observatory is hemispherical, and constructed with wood ribs, sheeted with wood and covered with copper. The dome has two slits, each 3 feet 8 inches in width, parallel with each other, and 5 feet 8 inches from centre to centre. The shutters of the lower half of each slit slide horizontally round the dome, and the upper halves slide upon and over the top of the dome, so that both slits can be opened full breadth from the horizontal to 18 inches beyond the zenith. By opening both slits the observatory is soon cooled down to the external temperature; but there is one disadvantage in this dual slit plan—it gives the dome a pole, which in some positions of the telescope is a little troublesome.

The latitude of the observatory is N. 51° 3′ 7″; longitude, E. $0^h\ 0^m\ 37^s$.

The site of the observatory was selected after much inquiry and investigation as to probability of the occurrence of numerous clear intervals of sky during the year suitable for the pursuit of stellar photography, and although it is premature to express a decided opinion, I am quite safe in stating that this locality is an improvement upon the former site of my observatory at Maghull.

It may interest some to know that I commenced building the observatory and house in the month of September 1889, and by September 1890 the buildings were finished and occupied, and some ten tons weight of telescopes, apparatus, and books were dismounted, conveyed, and re-erected on Crowborough Hill within twelve months time.

Accompanying is a photograph of the buildings.

The photographic work was continued at Maghull till the month of June 1890, and resumed at Crowborough in the following October.

Observations of the Planets Victoria and Sappho and comparison stars made with the Meridian Circle at Dunsink. By Arthur A. Rambaut, M.A., Assistant Astronomer at Dunsink Observatory.

(*Communicated by Sir Robert Ball.*)

In accordance with a request of Dr. Gill, the meridian circle and chronograph of the Dunsink Observatory were employed during the summer, autumn, and part of the winter of 1889–90, in observing the minor planets *Victoria* and *Sappho*, as well as the list of comparison stars selected by Dr. Gill for heliometer observations of parallax.

A precisely similar series of observations had been made during the previous year upon the planet *Iris* and comparison stars, the results of which were published in vol. xlix., No. 5, of the *Monthly Notices*.

In passing I should like to take this opportunity to correct a misprint which escaped my notice on p. 313 and subsequent pages of that communication. The date for which the places are computed is there given as 1880·0 throughout the whole list of separate results, instead of 1888·0, as it ought to be. This misprint is, however, the less likely to have misled anybody as the means of these results are correctly given in a collected list at the end of the paper as being for 1888·0.

I regret to say that the observations contained in the present communication are not so complete as might have been wished. Those of the comparison stars for *Victoria* in particular are a mere fragment of what it was proposed to obtain, owing to frequent interruption which occurred in the work; and although the results for the *Sappho* list are more satisfactory, there are still some stars of which I failed to get as many observations as suggested by Dr. Gill.

The places of the stars given below are, as in the case of the *Iris* list, differential, both in right ascension and declination, the clock error and the equator point of the circle being always determined by observations of a few stars selected from the *Berliner Jahrbuch*.

(I.) *Victoria and Comparison Stars.*—In the case of the *Victoria* series the standard stars selected were:—

List of Standard Stars.

No.	No. in Fund. Cat.	Name.	Mean R.A. 1889·0.	Mean Decl. 1889·0.
			h m s	° ′ ″
1	257	η Serpentis	18 15 33·936	− 2 55 36·96
2	266	θ Serpentis p.	18 50 42·062	+ 4 3 35·53
3	269	λ Aquilæ	19 0 21·464	− 5 2 54·37
4	604	π Sagittarii	19 3 9·754	−21 11 58·31
5	290	ϵ Delphini	20 27 54·589	+10 55 34·83
6	610	υ Capricorni	20 33 43·848	−18 31 44·22
7	297	ϵ Aquarii	20 41 40·012	− 9 54 6·35
8	256	δ Ursæ Min. U.C.	18 8 7·059	+86 36 40·98
9	111	51 H. Cephei L.C.	6 48 16·901	+87 13 9·41
10	508	76 Draconis	20 50 35·033	+82 7 10·40

The numbers in the eighth column of the following table refer to this list, the symbol (α) after a number denoting that the corresponding star has only been observed in Right Ascension. This symbol has been omitted in the case of the last three stars on the list, which were observed only in right ascension for the purpose of determining the azimuth error of the instrument. In other respects the table is similar to the corresponding one in the *Iris* observations, and requires no further explanation.

It should be remarked that throughout the *Victoria* observations the instrument was in the position Clamp W.

Table of Instrumental Corrections at $19^h{\cdot}5$ *Sidereal Time.*

Date. 1889.	Incl. s	Azim. s	Collim. s	$\Delta t + b \sec\phi$. s	Equator Point (S.) ° ′ ″	(N.) ″	Standard Stars.
June 10	+0·184	−0·068	+0·080	− 33·41	171 36 27·30	26·90	3(α), 4, 5, 6, 9
July 3	+0·243	−0·148	+0·051	− 72·11		27·36 27·03	2, 3, 5, 6, 8
29	+0·154	−0·159	+0·022	−127·10		25·73 25·61	1, 2, 3, 5, 6, 8
Aug. 17	+0·221	+0·276	+0·056	− 48·15		26·90 27·41*	3, 5, 6, 7, 10
20	+0·198	+0·214	+0·047	− 54·88		26·78 26·80	1, 2, 3, 6, 7, 8

Observations of the planet Victoria.

[The places given in this list are not corrected for annual aberration or parallax.]

Date. 1889.	App. R.A. h m s	App. Decl. ° ′ ″	Remarks.
July 3	19 54 15·66	−5 44 45·6	V.v. faint. Dark field.
29	33 28·78	−4 40 5·9	Faint. Bright field.
Aug. 17	24 56·71	−5 29 28·9	
20	24 41·05	−5 41 35·1	Dark field. Through clouds.

* Only two readings of Nadir-point.

Observations of Victoria Comparison Stars.

No.	D.M.	Date. 1889.	R.A. 1889·0. h m s	Decl. 1889·0. ° ′ ″	Remarks.
a	−8°, 4887	July 3	19 6 39·39	−8 7 27·1	
		29	39·44	27·7	
		Aug. 17	39·50	29·5	
		20	39·35	27·5	Decl. good.
			19 6 39·420	−8 7 27·95	
b	−5°, 4936	June 10	19 14 37·28	−5 37 21·3	Unsteady.
		July 3	37·38	19·6	Perhaps a little too much south.
		29	37·30	20·6	
		Aug. 17	37·36	22·3	
		20	37·31	21·5	
			19 14 37·326	−5 37 21·06	
1	−6°, 5151	June 10	19 21 25·22	−5 57 22·2	Unsteady.
		July 3	25·30	20·2	V. faint. Dark field.
			19 21 25·260	−5 57 21·20	
2	−6°, 5158	July 29	19 23 2·71	−6 24 0·2	Unsteady. Bright field.
6	−5°, 5006	June 10	19 27 50·40	−4 58 49·6	Unsteady.
		July 3	50·61	49·4	V. faint. Dark field.
		29	50·53	49·1	Bright field.
			19 27 50·513	−4 58 49·37	
9	−5°, 5021	Aug. 20	19 30 41·13	−5 1 2·2	
12	−4°, 4861	17	19 31 54·00	−4 53 40·6	
15	−4°, 4883	June 10	19 35 55·94	−4 32 50·5	Unsteady.
		July 3	56·09	49·2	Faint. Dark field.
		Aug. 20	56·09	49·4	Dark field. Clouds.
			19 35 56·040	−4 32 49·70	
16	−4°, 4903	July 29	19 39 23·65	−4 47 22·3	Dark field.
		Aug. 17	23·77	23·5	Dark field.
			19 39 23·710	−4 47 22·90	
17	−4°, 4916	Aug. 20	19 40 59·39	−3 56 0·0	Dark field.

No.	D.M.	Date 1839	R.A. 1839·0 h m s	Decl. 1839·0 ° ′ ″	Remarks.
19	−4°, 4925	June 10	19 43 4·49	−4 45 17·1	Unsteady.
		July 3	4·54	18·8	Dark field.
		29	4·54	20·3	Dark field.
		Aug. 17	4·40	17·8	Dark field.
			19 43 4·492	−4 46 19·00	
22	−4°, 4960	Aug. 20	19 47 27·16	−4 51 31·4	Dark field.
23	−5°, 5099	July 3	19 48 22 59	−5 19 59·3	
		Aug. 17	22·46	59·9	Dark field.
			19 48 22·525	−5 19 59 60	
24	−5°, 5120	June 10	19 51 25·92	−4 58 53·5	Unsteady. Daylight getting very bright.
		July 29	25·94	52·4	
			19 51 25·930	−4 58 52·95	
27	−4°, 4984	Aug. 20	19 52 38·10	−4 39 16·2	Dark field. Good.
28	−4°, 4992	Aug. 17	19 54 57·31	−4 36 53·7	
31	−8°, 5205	June 10	19 57 4·84	−8 0 13·7	Unsteady. Daylight getting very bright.
32	−5°, 5144	July 29	19 57 21·86	−4 56 27·6	Bright field.
		Aug. 20	21·69	27·8	Bright field.
			19 57 21·775	−4 56 27·70	
34	−4°, 5016	Aug. 17	20 0 44·87	−4 44 4·4	
35	−7°, 5169	July 3	20 0 46·87	−7 19 56·2	Dark field.
37	−9°, 5382	July 3	20 5 8·99	−9 10 13·2	Dark field.
		29	8·95	12·7	Bright field. Good.
		Aug. 17	8·98	13·7	Set in decl. after transit at IV. Dark field.
		20	8·82	12·1	
			20 5 8·935	−9 10 12·92	
o	−6°, 5451	June 10	20 14 31·40	−6 42 29·0	Unsteady.
		July 3	31·60	29·3	
		29	31·58	28·1	
		Aug. 17	31·58	29·8	
		20	31·52	29·2	
			20 14 31·536	−6 42 29·08	

No.	D.M.	Date. 1889.	R.A. 1889·0 h m s	Decl. 1889·0 ° ′ ″	Remarks.
d	−3°, 4888	July 3	20 19 55·06	−3 9 35·6	
		29	54·95	34·5	
		Aug. 17	55·08	35·6	
		20	55·04	34·2	
			20 19 55·032	−3 9 34·98	

(II.) *Sappho and Comparison Stars.*—The standard stars selected from the *Berliner Jahrbuch* for the *Sappho* series are contained in the following list:—

List of Standard Stars.

No.	No. in Fund. Cat.	Name.	R.A. 1889·0 h m s	Decl. 1889·0 ° ′ ″
1	538	ϕ Pegasi	23 46 50·439	+18 30 13·34
2	336	ω Piscium	23 53 36·659	+ 6 14 55·58
3	339	12 Cæti	0 24 22·442	− 4 34 14·84
4	25	o Piscium	1 39 31·894	+ 8 35 55·56
5	29	ξ Piscium	1 47 48·536	+ 2 38 21·19
6	33	α Arietis	2 0 54·962	+22 56 14·04
7	334	γ Cephei, U.C.	23 34 47·756	+77 0 45·76
8	168	4 H. Draconis, L.C.	12 6 59·505	+78 13 59·42

The last two stars on this list, Nos. 7 and 8, have been observed only in right ascension for the determination of the azimuth correction. Both of these were observed on every occasion with the exception of the three following dates—November 18 and 28 and December 15—on which clouds interfered with the transit of one or other of them.

Table of Instrumental Corrections at $0^h.5$ *Sidereal Time.*

Date.	Clamp.	Incl.	Azim.	Collim.	$\Delta t + b \sec\phi$	Equator Point (S.)	(N.)	Standard Stars.
1889.		s	s	s	R	° ′ ″	″	
Aug. 30	W	+0·215	+0·079	+0·081	− 76·16	171 36 27·48	26·42	1, 2, 3, 4, 5, 7, 8
Sept. 17	„	+0·229	+0·022	+0·040	−111·74	28·48	28·49	1, 2, 3, 4, 5, 7, 8
19	„	+0·252	+0·139	+0·062	−116·02	29·55	28·96	1, 2, 3, 4, 5 7, 8
24	„	+0·189	+0·092	+0·025	−126·50	28·57	27·73	1, 2, 4, 5, 7, 8
25	„	+0·187	+0·123	+0·052	−128·42	28·81	28·28	1, 2, 3, 7, 8
Oct. 7	„	+0·100	+0·013	+0·006	−150·26	28·55	28·52	1, 2, 4, 5, 7, 8
8	„	+0·129	+0·343	+0·129	−152·70	29·72	28·68	1, 2, 3 (a), 4, 5, 7, 8
10	„	+0·078	+0·117	+0·078	−156·58	28·51	27·57	1, 2, 3, 4, 5, 7, 8
11	„	+0·084	+0·200	+0·084	−158·46	29·31	28·36	1, 2, 3, 4, 5, 7, 8
12	„	+0·078	+0·088	+0·078	−160·11	28·52	27·91	1, 2, 3, 4, 5, 7, 8
13	„	+0·081	+0·220	+0·081	−161·92	29·21	28·48	1, 2, 3, 4, 5, 7, 8
30	„	+0 033	+0·011	[0·000]	−190·14	28·12	27·04	1, 2, 3, 4, 5, 7, 8

1889. Nov. 16	E	s +0·081	s +0·264	s +0·081	s −32·63	° ′ ″ 171 37 39·81	″ 39·93	1, 2, 3, 4, 5, 7, 8
18	,,	+0·055	+0·210	+0·055	−34·83	39·16	39·83*	3, 4, 5, 8
19	,,	+0·056	+0·128	+0·056	−35·95	39·66	39·52	1, 2, 3, 4, 5, 7, 8
25	,,	+0·077	+0·273	+0·077	−44·19	40 62	40·56	1, 2, 3, 4, 5, 7, 8
27	,,	+0·042	−0·033	−0·041	−47·35	40·01	39·86	1, 2, 3, 4, 5, 7, 8
28	,,	+0·035	−0·026	[−0·033]	−48·92	40·47	...	3, 5, 6, 8
Dec. 7	,,	−0·022	+0·207	+0·043	−59·95	39·10	39·03	1, 2, 3, 4, 5, 7, 8
10	,,	−0·040	+0·221	+0·068	−63·63	39·01	38·17*	1, 2, 3, 4, 5, 7, 8
11	,,	−0·022	+0·088	+0·049	−64·88	40·61	40·27	1, 2. 3, 4, 5, 7, 8
15	,,	−0·062	−0·095	+0·006	−70·02	38·76	...	1, 2, 3, 7
20	,,	0·000	+0·070	+0·059	−74·14	40·26	...	1, 2, 3, 4, 5, 7, 8
24	,,	+0·008	+0·072	+0·059	−78·50	39 74	...	1, 2, 3, 4, 5, 7, 8
1890. Jan. 2	W	−0·039	−0·074	+0·026	−86·79	171 36 26·05	25·87†	1, 2, 3, 4, 5, 7, 8

* Only two readings of the Nadir point.

† Only one reading.

Observations of the Planet Sappho.

[The places given in this list are not corrected for annual aberration or parallax.]

Date.	App. R.A.	App. Decl.	Remarks.
	h m s	° ′ ″	
Sept. 17	1 9 9·73	+17 9 38·5	Dark field. Appears 9m.
24	1 5 34·82	+16 9 49·7	Distinctly fainter than D.M. + 16°, 123, slightly fainter than, but almost exactly equal to D.M. + 15°, 173. A very deliberate, good comparison. Estimated mag. 9·2.
Oct. 7	0 56 52·52	+13 42 7·9	Dark field.
8	0 56 10·24	+13 29 25·0	
10	...	+13 3 38·3	Appeared through clouds just at edge of field.
11	0 54 4·89	+12 50 41·8	Distinctly brighter than D.M. + 12°, 120, a little brighter than D.M. + 12°, 123. Estimated mag. 8·9.
12	0 53 23·97	+12 37 39·8	Seemed same mag. as D.M. + 12°, 120 (i.e. 9·5), but comparison was hurried.
13	0 52 43·57	+12 24 34·6	Estimated 9m·2. Brighter than D.M. + 8°, 139. Dark field.
30	0 43 59·08	+ 8 51 31·1	Varying in brightness through clouds. Dark field.

Observations of Sappho Comparison Stars.

No.	D.M.	Date. 1889.	Clamp.	R.A. 1889·0. h m s	Decl. 1889·0. ° ′ ″	Remarks.
e	+ 10°, 065	Aug. 30	W	0 31 32·15	+ 10 49 32·3	
		Sept. 17	,,	31·97	31·2	
		19	,,	32·05	32·7	
		24	,,	32·09	32 0	
		25	,,	31·95	33 2	
		Oct. 7	,,	32·05	33 0	
		8	,,	32·04	31·5	Only five wires.
		10	,,	32·01	31·9	
		11	,,	32·09	31·8	
		12	,,	32·04	32·0	Good.
		13	,,	32·02	32·0	
		30	,,	31·99	31·6	Definition bad.
		Nov. 16	E	32·03	32·1	
		18	,,	32·10	32·2	
		19	,,	32·02	31·8	
		25	,,	32·03	32·9	
		27	,,	32·09	31·9	Decl. bad. Very unsteady when setting.
		28	,,	32·11	32·6	Rather faint. Clouds.
		Dec. 7	,,	31·99	33·1	
		10	,,	32·05	32·7	See note (*a*).
		11	,,	32·02	32·9	Dark field.
		15	,,	31·90	32·6	Dark field.
		20	,,	32·05	32·9	
		24	,,	32·03	32·2	
		1890. Jan. 2	W	32·02	32·0	
				0 31 32·036	+ 10 49 32·28	

No.	D.M.	Date. 1889.	Clamp.	R.A. 1889·0. h m s	Decl. 1889·0. ° ′ ″	Remarks.
f	+15°, 106	Aug. 30	W	0 37 4·28	+16 3 23·7	
		Sept. 17	„	4·20	24·5	
		19	„	4·29	24·4	
		24	„	4·34	23·5	
		25	„	4·20	23·9	
		Oct. 7	„	4·27	24·0	
		8	„	4·26	23·1	
		10	„	4·22	23·6	
		11	„	4·29	23·9	
		12	„	4·32	23 9	
		13	„	4·27	22·6	
		30	„	4·28	23·3	Definition bad. Set hurriedly in decl., but seemed good.
		Nov. 16	E	4·24	22·7	
		18	„	4·26	23·0	
		19	„	4·24	22·8	
		25	„	4·24	23·0	
		27	„	4·32	23·9	
		28	„	[4·43]	23·2	Dark field. Very faint through clouds.
		Dec. 7	„	4·25	22·6	
		10	„	4·23	22·7	
		11	„	4·26	22·6	Dark field.
		15	„	4·16	23·8	See note (*b*).
		20	„	4·27	22·8	
		24	„	4·27	22·6	
		1890. Jan. 2	W	4·28	24·2	
				0 37 4·260	+16 3 23·37	
		1889.				
1	+ 8°, 110	Aug. 30	W	0 42 25·31	+ 8 36 56·4	Rather faint for bright field.
		Sept. 17	„	25·25	57·2	
		Oct. 12	„	25·24	56·9	Faint.
		Nov. 18	E	25·28	56·1	
		28	„	25·25	57·2	Dark field. Faint through clouds.
				0 42 25·266	+ 8 36 56·76	

No.	D.M.	Date.	Clamp.	R.A. 1889·0.	Decl. 1889·0.	Remarks.
		1889.		h m s	° ′ ″	
2	+ 9°, 090	Sept. 19	W	0 42 31·09	+ 9 39 11·8	
		Oct. 11	,,	31·05	11·5	
		Dec. 10	E	31·06	11·3	Faint through clouds.
				0 42 31·067	+ 9 39 11·53	
3	+ 11°, 102	Sept. 25	W	0 44 24·23	+ 11 13 36·8	Dark field.
		Nov. 25	E	24·35	36·2	Dark field. Not so bright as 8m·6.
		27	,,	24·35	36·5	Dark field.
		1890. Jan. 2	W	24·33	...	Dark field.
				0 44 24·315	+ 11 13 36·50	
4	+ 9°, 097	1889. Oct. 7	W	0 44 46·76	+ 9 48 25·7	
		Nov. 16	E	46·77	23·5	
		Dec. 11	,,	46·78	24·6	
				0 44 46·770	+ 9 48 24·60	
5	+ 11°, 106	Sept. 24	W	0 45 46·18	+ 12 10 52·3	
		Oct. 8	,,	46·12	52·4	Thin clouds.
		13	,,	46·14	51·9	
		Nov. 19	E	46·10	52·3	
		Dec. 7	,,	46·14	52·8	
		15	,,	46·08	53·1	Dark field. Decl. good.
				0 45 46·127	+ 12 10 52·47	
6	+ 9°, 099	Oct. 10	W	0 46 20·51	+ 9 59 53·0	Dark field. Clouds.
		Dec. 20	E	20·46	53·3	
		24	,,	20·46	52·4	Dark field. Only 5 wires. Decl. good.
		1890. Jan. 2	W	20·34	52·2	Dark field. R.A. ½ weight.
				0 46 20·457	+ 9 59 52·72	
7	+ 12°, 104	1889. Oct. 12	W	0 46 40·02	+ 13 2 44·5	
		Nov. 28	E	40·01	43·9	Dark field.
				0 46 40·015	+ 13 2 44·20	
8	+ 9°, 101	Aug. 30	W	0 47 0·68	+ 9 12 3·9	
		Dec. 10	E	0·62	6·2	
				0 47 0·650	+ 9 12 5·05	

No.	D.M.	Date. 1889.	Champ.	R.A. 1889·0. h m s	Decl. 1889·0. ° ′ ″	Remarks.
9	- 10°, 105	Sept. 17	W	0 48 3·00	+ 10 31 11·7	
		19 „		2·92	11·9	
		Oct. 11 „		2·91	14·4	
		Nov. 18	E	3·01	11·8	Faint.
				0 48 2·960	+ 10 31 12·45	
10	- 12°, 108	Oct. 30	W	0 49 12·00	+ 12 14 41·4	
		Nov. 25	E	11·96	44·8	
				0 49 11·980	+ 12 14 44 60	
11	- 13°, 127	Sept. 25	W	0 50 19·67	+ 13 21 1·9	
		Nov. 19	E	19·62	1 1	
		Dec. 20 „		19·67	1·8	
				0 50 19 653	+ 13 21 1·60	
12	- 11°, 118	Oct. 8	W	0 50 40·41	+ 12 6 44·3	Very changeable through clouds.
		Nov. 27	E	40·39	45·4	Dark field.
				0 50 40·400	+ 12 6 44·85	
13	+ 13°, 130	Oct. 10	W	0 50 52·36	+ 14 10 32·0	Dark field. V. faint through clouds.
		Dec. 7	E	52·24	29·3	
				0 50 52·300	+ 14 10 30·65	
14	+ 9°, 110	Oct. 7	W	0 50 59·21	+ 9 24 54·4	Dark field.
		Dec. 11	E	59·27	53·6	Faint.
				0 50 59·240	+ 9 24 54·00	
15	+ 11°, 120	Sept. 24	W	0 51 32·84	+ 11 49 44·8	Definition bad.
		Nov. 16	E	32·80	46·1	
		Dec. 24 „		32·93	46·8	
				0 51 32·857	+ 11 49 45·90	
16	+ 12°, 119	Aug. 30	W	0 52 4·99	+ 13 5 44·8	
		Nov. 18	E	5·04	45·3	
		28 „		4·99	45·4	Dark field. Excellent.
		Dec. 15 „		4·89	46·1	Dark field. Decl. good.
		1890. Jan. 2	W	5·01	41·2	
				0 52 4 984	+ 13 5 45·16	

No.	D.M.	Date. 1889.	Clamp.	R.A. 1889·0. h m s	Decl. 1889·0. ° ′ ″	Remarks.
17	+13°, 143	Sept. 17	W	0 53 53·66	+14 0 39·2	
		Dec. 10	E	53·71	37·5	Dark field.
				0 53 53·685	+14 0 38 35	
18	+10°, 115	Oct. 30	W	0 55 25·55	+10 34 59 0	
		Dec. 20	E	25·55	59·3	
				0 55 25·550	+10 34 59 15	
19	+11°, 135	Sept. 19	W	0 55 32·91	+11 18 53·0	Dark field.
		Nov. 19	E	32·84	50·6	
		25	„	33·03	...	
		27	„	32·92	51·5	
		Dec. 12	„	32·83	51·6	
				0 55 32·906	+11 18 51 67	
20	+13°, 150	Sept. 25	W	0 56 43·39	+13 39 19·8	
		Nov. 18	E	43·57	18·3	
		Dec. 11	„	43·57	17·1	
				0 56 43·510	+13 39 18·40	
21	+15°, 154	Nov. 16	E	0 57 9·69	+15 32 26·5	
		1890. Jan. 2	W	9·62	26·5	Very faint.
				0 57 9·655	+15 32 26·50	
22	+12°, 126	1889. Sept. 24	W	0 57 16·37	+12 27 10 1	
		Dec. 24	E	16·35	10·8	
				0 57 16·360	+12 27 10·45	
23	+13°, 155	Oct. 13	W	0 58 0·46	+13 20 27·5	
24	+14°, 163	Aug. 30	„	0 59 13·72	+14 20 57·1	
		Sept. 17	„	13·73	56·6	
		Oct. 12	„	13·72	56·3	Unsteady. Dark field.
		Nov. 28	E	13·78	56·9	
		Dec. 15	„	13·67	56·5	
				0 59 13·724	+14 20 56 68	

No.	D.M.	Date. 1889.	Clamp.	R.A. 1889·0. h m s	Decl. 1889·0. ° ′ ″	Remarks.
25	+14°, 168	Oct. 11	W	0 59 57·06	+14 23 16·4	Illumination of wires bad.
		Dec. 10	E	56·97	15·8	Dark field.
				0 59 57·015	+14 23 16·10	
25*a*	+14°, 169	Nov. 19	E	1 0 4·30	+14 47 23·8	
		25	„	[4·65]	[22·9]	See note (*c*).
		Dec. 7	„	4·29	24·6	
				1 0 4·295	+14 47 24·20	
26	+15°, 159	Nov. 27	E	1 0 29·64	+15 43 10·4	
		Dec. 20	„	29·61	10·0	Very faint through clouds.
				1 0 29·625	+15 43 10·20	
27	+15°, 164	Sept. 19	W	1 1 59·51	+15 16 15·7	Very faint through clouds. Dark field.
		Oct. 8	„	59·47	15·5	
		Nov. 18	E	59 52	16·3	
				1 1 59·500	+15 16 15·83	
28	+16°, 116	Oct. 7	W	1 2 2·09	+16 49 12·0	
		Dec. 11	E	2·17	10·9	Good.
				1 2 2·130	+16 49 11·45	
29	+16°, 119	Sept. 25	W	1 2 34·87	+17 3 [43·9]	See note (*d*).
		Oct. 10	„	34·84	41·0	Dark field.
		13	„	34·84	40·7	Definition not good. Dark field.
		Nov. 16	E	34·84	41·1	
		Dec. 24	„	34·88	41·2	
				1 2 34·854	+17 3 41·32	
30	+14°, 175	Sept. 17	W	1 4 18·33	+15 4 59·2	
		Nov. 28	E	18·32	59·4	
		Dec. 15	„	18·20	59·6	
				1 4 18·283	+15 4 59·40	
31	+17°, 166	Oct. 12	W	1 5 3·71	+17 48 6·8	
		Dec. 10	E	3·72	6·5	Dark field.
				1 5 3·715	17 48 6·65	

No.	D.M.	Date 1889.	Clamp.	R.A. 1889·0. h m s	Decl. 1889·0. ° ′ ″	Remarks.
32	+16°, 123	Aug. 30	W	1 5 10·11	+16 11 12·5	
		Oct. 30	„	10·23	12·7	Definition bad.
		Nov. 19	E	10·18	12·9	
		Dec. 20	„	10·24	12·4	
				1 5 10·190	+16 11 12·62	
33	+13°, 175	Oct. 1	W	1 5 24·04	+14 6 6·1	
		Nov. 27	E	24·04	6·0	
		Dec. 7	„	24·05	6·9	
				1 5 24·043	+14 6 6·33	
34	+15°, 175	Oct. 7	W	1 6 55·79	+16 10 29·7	
		Dec. 11	E	55·82	29·3	
				1 6 55·805	+16 10 29·50	
35	+15°, 177	Oct. 8	W	1 8 13·76	+15 32 45·1	
		13	„	13·80	45·4	Dark field. Good.
		Nov. 16	E	13·82	44·2	
		18	„	13·88	44·9	
				1 8 13·815	+15 32 44·90	
36	+16°, 129	Oct. 10	W	1 10 15·81	+17 2 54·1	Dark field. Clouds.
		12	„	15·72	53·9	
		30	„	15·78	53·7	
		Nov. 27	E	15·81	53·7	Ill-defined.
		28	„	15·79	54·0	
		Dec. 24	„	15·75	53·2	
				1 10 15·777	+17 2 53·77	
37	+15°, 185	Sept. 19	W	1 11 34·45	+15 46 10·2	Very faint through clouds at times. Dark field.
		25	„	34·25	9·1	Dark field. Very faint.
		Oct. 11	„	34·30	7·7	
		Nov. 19	E	34·35	9·4	Dark field.
		Dec. 7	„	34·41	9·0	Dark field. Light clouds.
		10	„	34·26	8·2	Dark field.
				1 11 34·337	+15 46 8·93	

No.	D.M.	Date. 1889.	Clamp.	R.A. 1889·0. h m s	Decl. 1889·0. ° ′ ″	Remarks.
38	+17°, 183	Aug. 30	W	1 12 26·01	+17 59 30·8	
		Sept. 24	,,	26·10	31·8	
		Oct. 7	,,	26·06	32·9	
		8	,,	25·99	32·2	
		Nov. 18	E	26·00	30·8	
		Dec. 11	,,	26·05	31·6	
		15	,,	25·95	31·9	Dark field.
		20	,,	26·04	31·7	
				1 12 26·025	+17 59 31·71	
g	+10°, 171	Aug. 30	W	1 17 2·12	+10 47 13·0	Only five wires.
		Sept. 17	,,	2·19	14·7	
		19	,,	2·16	12·8	Declination appeared good. Only five wires.
		24	,,	2·20	13·7	
		25	,,	2·03	14·7	Very changeable through clouds. Dark field.
		Oct. 7	,,	2·17	14·2	
		8	,,	2·16	14·2	
		10	,,	2·17	13·6	Very good.
		11	,,	2·17	13·7	Very good.
		12	,,	2·14	13·9	
		13	,,	2·16	14·1	
		30	,,	2·20	13·8	
		Nov. 16	E	2·18	13·4	
		18	,,	2·19	13·5	
		19	,,	2·15	12·8	
		25	,,	2·11	14·4	Dark field.
		27	,,	2·23	14·3	Ill-defined.
		28	,,	2·21	14·4	
		Dec. 7	,,	2·16	13.6	Dark field.
		10	,,	2·17	14·5	Good.
		11	,,	2·16	13·6	
		15	,,	2·17	15·6	Dark field. Decl. seems good.
		20	,,	2·14	14·0	
		24	,,	2·13	13·5	
		1890. Jan. 2	W	2·11	14·3	Good.
				1 17 2·159	+10 47 13·93	

No.	D.M.	Date. 1889.	Clamp.	R.A. 1889·0. h m s	Decl. 1889·0. ° ′ ″	Remarks.
h	+16°, 154	Aug. 30	W	1 22 25·99	+16 30 16·3	
		Sept. 17	„	26·04	16·9	
		19	„	25·96	16·5	
		24	„	25·98	16·1	
		25	„	25·80	18·3	Dark field. Just visible through clouds.
		Oct 7	„	25·95	17·0	
		8	„	25·87	16·6	
		10	„	25·92	16·7	Very good.
		11	„	25·87	16·9	Definition beautiful.
		12	„	25·92	15·9	Rather unsteady.
		13	„	25·95	16·9	
		30	„	25·92	16·4	
		Nov. 16	E	25·95	17·5	
		18	„	25·93	17·5	
		19	„	25·94	16·6	
		25	„	25·98	16·8	
		27	„	26·04	17·2	Good.
		28	„	25·99	18·0	
		Dec. 7	„	25·88	16·9	
		10	„	25·93	16·8	Good.
		11	„	26·01	16·6	Very good.
		15	„	25·82	18·0	Dark field. Very faint.
		20	„	25·91	19·1	Variable and ill-defined through clouds.
		24	„	25·96	17·3	
		1890. Jan. 2	W	25·98	16·4	Good.
				1 22 25·940	+16 30 17·01	

Notes.

(*a*) Variable in brightness. Faint at times through clouds. Bright field.

(*b*) Transit over first set of wires good in a bright field. Clouds at middle wire. Decl. and second set of wires observed in dark field.

(*c*) Only three wires. Set in decl. through a break in clouds.

(*d*) Microscope V. read at once. The other three not till after the transit of *h*. This was done to get *Sappho*, which, however, was lost in clouds. Dark field. Weight, $\frac{1}{2}$ in decl.

Probable Error of the Resulting Places.

In computing the probable error of these results, I have contented myself with the observations of the four stars which I call *e*, *f*, *g*, and *h*, as it appeared that the comparatively large number of observations obtained for each of these stars would give a more reliable result than could be obtained by taking the difference between each separate result and the mean of a small number of results for each star as the basis of calculation. All the stars of the list, too, being included between +8° and +18° of declination, and all being observed under exactly similar circumstances, any result applicable to the stars *e*, *f*, *g*, *h* will be equally so to the other stars of the list.

From all the observations of *e*, *f*, *g*, *h*, including the right ascension of *f*, on November 28, although this observation has been neglected in taking the mean, I find as the probable error of a single determination of right ascension, reduced to the equator, the quantity

$$\pm 0^{s}\cdot 033,$$

while the probable error of a single determination of declination similarly computed is

$$\pm 0''\cdot 42$$

Spectroscopic Results for the Motions of Stars in the Line of Sight, obtained at the Royal Observatory, Greenwich, in the year 1890. No. XIV.

(*Communicated by the Astronomer Royal.*)

The Results here given are in continuation of those printed in the *Monthly Notices*, vol. xxxvi. p. 318, vol. xxxvii. p. 32, vol. xxxviii. p. 493, vol. xli. p. 109, vol. xlii. p. 230, vol. xliii. p. 81, vol. xliv. p. 89, vol. xlv. p. 330, vol. xlvi. p. 126, vol. xlvii. p. 101, vol. xlviii. p. 116, vol. xlix. p. 127, and vol. l. p. 111.

The observations were made with the "half-prism" spectroscope, one "half-prism," with a dispersion of about 18½° from A to H, being used throughout. A magnifying power of 14 was employed.

The cylindrical lens has always been used in front of the slit, as in the observations made previously to 1881 and since 1882, March 14. The observations of the Sun, Moon, and planets have been made as a check on the general accuracy of the results.

The day specified in the first column is the civil day, and the hour is that of Greenwich civil time, commencing at Greenwich mean midnight, and reckoning from 0 to 24 hours.

The observations were made by Mr. Maunder throughout.

The observations in brackets on September 15 have been rejected, as the comparison with the sky spectrum afterwards showed that the spectroscope was out of adjustment.

Motions of Stars in the Line of Sight in Miles per Second, observed with the Half-prism Spectroscope.

(+ denotes Recession; −, Approach.)

Date. 1890. G.C.T.			No. of Meas.	Line.	Earth's Motion in miles per sec.	Concluded Motion of Star. Measd.	Estimd.	Remarks.
	d	h						
					α Andromedæ.			
Aug.	2	0	2	F	−14·3	−10·8	−14·3	Star-line seen fairly well.
	7	0	2	F	−13·7	−58·9	−49·9	Star-line faint.
Sept.	9	0	2	F	− 7·3	− 8·1	− 7·1	Star-line seen fairly well.
	13	23	2	F	− 6·0	−12·5	−14·4	Star-line seen fairly well.
Oct.	1	22	1	F	− 1·2	−11·5	− 7·1	Definition bad.
	9	22	2	F	+ 1·1	+ 1·0	− 1·1	Definition bad.
	11	22	2	F	+ 1·7	−11·9	−14·2	Definition poor.
					β Cassiopeiæ.			
Aug.	7	1	2	F	−11·0	−26·7	−36·7	Star-line seen with difficulty.
Sept.	13	23	2	F	− 7·6	− 7·6	−10·3	Star-line faint.
Oct.	11	20	2	F	− 3·0	−13·6	−13·1	Star-line seen well.
					γ Pegasi.			
Sept.	9	0	2	F	− 6·5	+34·0	+30·6	Star-line seen fairly well.
	11	23	2	F	− 5·7	−54·0	−38·4	Spectrum faint.
	13	22	2	F	− 5·1	−45·2	−45·9	Star-line observed with difficulty.
Oct.	1	22	2	F	+ 0·3	−14·0	−14·8	Definition bad.
	9	22	2	F	+ 2·8	+ 3·6	+ 1·7	Definition poor.
	11	22	2	F	+ 3·4	+ 5·0	+ 5·6	Definition poor.
					α Cassiopeiæ.			
Sept.	15	22	2	b_1	− 8·6	(+36·2)	(+35·2)	Star-line exceedingly faint.
					γ Cassiopeiæ.			
Aug.	7	1	2	F	−11·8	− 7·2	− 8·9	Star-line feebly bright, and observed with great difficulty.
Sept.	13	23	2	F	− 9·3	+ 8·2	+ 9·3	
Oct.	11	20	2	F	− 4·9	+20·0	+20·4	
					δ Cassiopeiæ.			
Sept.	13	23	2	F	− 1·0	−13·5	−14·3	Star-line seen fairly well.
Oct.	11	20	2	F	− 6·0	+74·4	+53·6	Spectrum bright, but very unsteady. Definition bad.

Date. 1890. G.C.T.	No. of Meas.	Line	Earth's Motion in miles per sec.	Concluded Motion of Star. Measd.	Estimd.	Remarks.
			β Arietis.			
Oct. d h 9 22	2	F	− 4·9	− 8·2	− 8·6	Star-line seen fairly well.
			γ Andromedæ.			
Sept. 15 23	2	b_1	−12·3	(−12·9)	(−19·2)	Star-line very faint.
			β Persei.			
Mar. 3 23	2	F	+16·4	−53·0	−57·0	Measures made with great difficulty.
12 22	4	F	+15·2	−58·7	−54·0	Star-line seen fairly well.
Sept. 13 23	4	F	−15·0	+ 2·0	− 2·9	Star-line seen fairly well.
Oct. 9 23	2	F	−10·5	−52·7	−46·6	Star-line seen fairly well.
			α Persei.			
Mar. 12 22	2	F	+14·9	−44·4	−42·5	Star-line seen fairly well.
Sept. 14 0	2	F	−14·7	+ 0·6	− 3·2	Star-line seen fairly well.
Oct. 9 23	2	F	−11·1	+12·3	+11·1	Star-line seen fairly well.
			Aldebaran.			
Jan. 4 22	2	F	+11·2	+63·8	+38·3	Star-line seen with great difficulty.
Feb. 7 20	2	F	+17·7	+23·6	+35·6	Star-line seen with great difficulty.
18 23	2	F	+18·5	+18·7	+32·5	Star-line faint.
Mar. 12 22	2	F	+18·0	+16·8	+20·9	Star-line seen with great difficulty.
17 22	2	b_1	+17·4	+ 4·8	+24·4	Star-lines seen with great difficulty.
			Capella.			
Mar. 3 22	2	F	+17·1	+10·6	+23·5	Star-line seen fairly well.
12 22	2	F	+17·1	+14·7	+26·1	Star-line seen with great difficulty.
17 23	4	b_1	+16·9	+10·2	+32·4	Spectrum very unsteady.
Sept. 14 0	2	F	−16·7	+49·4	+54·1	Star-line faint.
15 23	2	b_1	−16·7	(+57·7)	(+66·0)	Star-line very faint.
			Rigel.			
Feb. 18 20	2	F	+15·5	+29·1	+22·8	Definition fair.
Mar. 3 20	4	F	+16·0	+30·5	+29·5	Spectrum faint and very unsteady.
12 20	2	F	+15·8	+14·7	+22·2	Definition bad.
Apr. 3 20	2	F	+13·7	+ 8·5	+ 6·3	Spectrum unsteady. Star-line faint.

Date. 1890. G.C.T.			No. of Meas.	Line.	Earth's Motion in miles per sec.	Concluded Motion of Star. Measd.	Estimd.	Remarks.
					γ Orionis.			
	d	h						
Feb.	18	20	2	F	+17·0	+16·7	+12·8	Definition poor.
Mar.	3	20	2	F	+17·8	+13·2	+14·5	Spectrum faint and very unsteady.
	12	21	2	F	+17·8	−20·7	−17·8	Star-line seen fairly well.
Apr.	3	20	2	F	+15·9	−22·3	−18·4	Star-line faint and seen with difficulty.
					β Tauri.			
Feb.	18	21	4	F	+17·5	− 8·3	− 8·6	Definition poor.
Mar.	3	20	2	F	+18·4	+12·4	+16·7	Spectrum faint, but fairly steady.
	12	21	2	F	+18·5	+ 7·7	+11·7	Star-line seen fairly well.
Apr.	3	21	2	F	+16·8	−32·8	−39·3	Star-line seen fairly well.
					δ Orionis.			
Feb.	18	21	4	F	+16·1	+13·2	+12·8	Star-line seen with great difficulty.
Mar.	12	21	4	F	+17·0	− 6·7	− 6·2	Spectrum faint.
					ε Orionis.			
Mar.	12	21	4	F	+16·9	+ 9·0	+13·7	Spectrum faint and very unsteady.
					ζ Orionis.			
Mar.	12	21	4	F	+16·8	−16·8	−15·5	Star-line faint.
					α Orionis.			
Mar.	17	22	4	b_1	+17·8	+ 4·9	+19·9	Spectrum very unsteady, star-lines seen with great difficulty.
	17	22	4	b_4	+17·8	+19·1	+27·9	
					β Aurigæ.			
Feb.	18	23	2	F	+15·4	−11·6	−10·3	Star-line seen well.
Mar.	3	22	2	F	+16·8	−27·0	−29·7	Star-line very ill-defined.
	12	22	2	F	+17·2	−53·4	−55·2	Spectrum fairly bright, but unsteady.
					γ Geminorum.			
Feb.	18	22	4	F	+14·8	(−10·3)	(−14·8)	Very unsatisfactory. Observations very discordant *inter se.*
Mar.	3	21	2	F	+16·9	+ 7·9	+13·5	Definition fair.
	12	23	2	F	+17·8	−39·5	−48·0	Star-line seen fairly well.
	28	23	4	F	+18·3	−74·1	−80·3	Spectrum bright, but rather unsteady.

Date. 1890. G.C.T.	No. of Meas.	Line.	Earth's Motion in miles per sec.	Concluded Motion of Star. Measd.	Estimd.	Remarks.
			Sirius.			
d h						
Feb. 18 21	4	F	+10·7	− 6·9	− 8·2	Spectrum very unsteady.
Mar. 3 21	6	F	+12·6	− 8·7	− 8·9	Measures very rough.
7 22	4	F	+13·0	−33·5	−34·7	Much cloud. Definition bad.
12 20	6	F	+13·4	−17·6	−18·9	Definition very bad.
Apr. 3 21	2	F	+14·1	−15·8	−18·3	Spectrum very unsteady.
			Castor.			
Feb. 18 22	2	F	+12·3	+38·8	+55·7	Star-line seen fairly well.
Mar. 3 22	2	F	−15·0	+23·8	+31·1	Star-line seen well.
12 23	4	F	+16·4	+ 9·7	+11·2	Spectrum bright and fairly steady.
22 0	2	F	+17·4	+ 3·7	+ 7·1	Star-line seen well.
29 0	2	F	+17·8	− 9·3	− 6·5	Star-line seen well.
Apr. 22 21	2	F	+17·3	+19·6	+28·8	Star-line seen well.
30 21	2	F	+16·6	−10·2	− 5·1	Star-line seen fairly well.
May 23 22	2	F	+12·7	+68·6	+55·2	Spectrum faint.
			Procyon.			
Feb. 18 22	2	F	+10·6	+ 1·4	+14·9	Star-line seen well.
Mar. 3 21	2	F	+13·6	+ 0·5	+11·3	Star-line seen well.
12 23	4	F	+15·2	−29·0	−28·2	Spectrum very unsteady.
21 23	2	F	+16·4	−30·7	−33·3	Star-line seen well.
29 1	4	F	+17·0	−26·9	−28·3	Star-line seen fairly well.
Apr. 22 21	4	F	+17·2	−33·5	−29·8	Star-line seen well.
30 21	2	F	+16·7	−12·0	− 7·5	Star-line seen fairly well.
			Pollux.			
Feb. 18 22	2	F	+11·6	−23·1	−21·8	Star-line seen with difficulty.
Mar. 3 21	2	F	+14·6	−23·7	−25·7	Star-line seen with great difficulty.
12 23	2	F	+16·1	−52·7	−67·9	Star-line seen fairly well.
17 23	2	b_1	+16·7	−27·6	−34·1	Star-lines seen with great difficulty.
22 0	2	F	+17·2	−68·4	−73·6	Star-line seen well.
29 0	2	F	+17·8	−53·7	−57·3	Star-line seen with difficulty.
Apr. 22 21	2	F	+17·7	−49·2	−47·6	Star-line seen fairly well.
30 21	2	F	+17·0	−61·6	−53·8	Measures made with difficulty.
May 23 22	2	F	+13·4	−61·4	−59·2	Star-line seen well.

Date. 1890. G.C.T.	No. of Meas.	Line.	Earth's Motion in miles per sec.	Concluded Motion of Star. Measd.	Estimd.	Remarks.
			Regulus.			
Mar. d 22 h 1	2	F	+10·1	−10·9	−10·1	Cloud passing. Measures rough.
29 1	2	F	+11·8	+17·1	+21·1	Star-line seen well.
Apr. 22 21	4	F	+16·3	− 0·5	+ 7·5	Star-line seen well.
30 22	2	F	+17·2	−55·6	−49·4	Star-line faint.
May 17 22	1	F	+17·9	+ 9·7	+18·7	Spectrum bright and steady. Star-line seen well.
21 22	2	F	+17·9	−66·1	−67·9	Measures made with difficulty.
23 22	2	F	+17·8	−12·1	−12·7	Star-line seen well.
June 2 22	2	F	+17·4	−16·2	−15·4	Observations interrupted by cloud.
			γ Leonis.			
Mar. 29 1	2	F	+11·8	−15·9	−17·5	Star-line faint and difficult to see.
Apr. 22 22	2	F	+16·2	−28·1	−25·4	Star-line faint and difficult to see.
30 22	2	F	+17·1	−44·8	−44·0	Star-line very faint.
May 21 22	2	F	+17·7	−27·1	−26·3	Star-line faint and difficult to see.
23 22	2	F	+17·6	−18·4	− 7·4	Star-line very faint. Measures rough.
			β Ursæ Majoris.			
May 7 23	2	F	+12·7	−71·5	−58·7	Star-line ill-defined.
			α Ursæ Majoris.			
May 8 0	2	F	+11·6	−46·2	−46·1	Measures very rough.
Sept. 15 22	2	b_1	− 7·5	(+50·5)	(+56·8)	Star-line very faint and seen with great difficulty.
			β Leonis.			
Mar. 29 2	2	F	+ 5·6	+20·7	+22·6	Star-line seen fairly well.
Apr. 22 22	2	F	+12·0	+13·5	+24·8	Star-line seen fairly well.
30 22	2	F	+13·6	−20·0	−19·4	Star-line seen fairly well.
May 21 22	2	F	+16·5	− 4·2	− 7·9	Star-line seen with difficulty.
23 23	2	F	+16·7	+18·7	+30·0	Spectrum unsteady. Star-line very difficult to bisect.
			γ Ursæ Majoris.			
May 7 23	2	F	+12·0	−35·9	−36·6	Star-line ill-defined.
			δ Ursæ Majoris.			
May 7 23	2	F	+10·9	+ 6·0	+16·7	Star-line ill-defined.

Date. 1890. G.C.T.	No. of Meas.	Line.	Earth's Motion in miles per sec.	Concluded Motion of Star. Measd.	Estimd.	Remarks.
			ε Ursæ Majoris.			
May d 7 h 22	2	F	+ 9·9	−56·0	−50·9	Star-line seen fairly well.
			Spica.			
Apr. 22 22	2	F	+ 3·3	+19·8	+23·6	Star-line seen fairly well.
30 23	2	F	+ 5·6	−28·1	−28·6	Star-line seen fairly well.
May 12 22	1	F	+ 8·9	−53·6	−54·9	Observations interrupted by cloud.
15 22	4	F	+ 9·7	−59·1	−53·1	Star-line seen fairly well.
21 23	2	F	+11·1	+26·6	+24·7	Measures made with great difficulty.
23 23	2	F	+11·6	−66·4	−67·6	Star-line seen well.
31 23	4	F	+13·3	−63·5	−49·8	Star-line seen well.
			ζ Ursæ Majoris.			
May 7 22	2	F	+ 8·9	−44·9	−54·9	Star-line ill-defined.
			η Ursæ Majoris.			
May 7 22	2	F	+ 8·2	−17·5	−22·0	Star-line ill-defined.
			Arcturus.			
Mar. 18 0	4	b_1	− 6·8	−28·6	−36·7	Spectrum very unsteady. Star-line distinct.
Apr. 22 22	2	F	+ 2·7	−26·6	−29·6	Star-line seen fairly well.
30 23	4	F	+ 4·8	−37·2	−41·2	Star-line seen fairly well.
May 5 22	2	F	+ 5·9	−33·4	−34·8	Star-line very faint.
7 21	2	F	+ 6·4	−31·6	−31·0	Star-line faint.
15 22	2	F	+ 8·2	−40·4	−42·5	Star-line faint and seen with difficulty.
21 23	2	F	+ 9·5	−45·5	−43·8	Star-line seen well.
23 23	2	F	+ 9·9	−57·5	−60·8	Star-line seen fairly well.
31 23	2	F	+11·3	−40·5	−37·0	Star-line seen fairly well.
June 27 23	2	F	+14·6	−37·7	−30·9	Star-line seen well now and then.
July 3 22	2	F	+15·0	−36·3	−35·5	Star-line seen with difficulty.
Aug. 6 22	2	F	+14·3	−55·0	−57·2	Star-line seen with great difficulty.
Sept. 15 21	4	b_1	+ 7·8	(−64·7)	(−62·0)	Spectrum faint and very unsteady.
			β Ursæ Minoris.			
Sept. 15 22	2	b_1	− 3·5	(−44·2)	(−40·9)	Star-line seen with great difficulty.

Date. 1890. G.C.T.		No. of Meas.	Line.	Earth's Motion in miles per sec.	Concluded Motion of Star. Measd.	Estimd.	Remarks.
				β Libræ.			
	d h						
Apr.	22 23	2	F	− 4·7	−16·6	−20·6	Star-line seen fairly well.
May	1 0	2	F	− 2·3	+ 6·7	+ 6·9	Star-line seen well.
	15 22	4	F	+ 2·2	−38·0	−40·3	Star-line seen well.
	24 0	2	F	+ 4·5	−22·9	−22·4	Star-line seen well.
	31 23	2	F	+ 6·8	−53·4	−47·4	Star-line seen fairly well.
June	6 23	2	F	+ 8·3	−47·5	−71·9	Star-line faint.
				α Coronæ Borealis.			
Apr.	22 23	4	F	− 1·8	+31·6	+36·3	Star-line seen fairly well.
May	15 23	2	F	+ 3·2	+35·1	+38·0	Star-line seen well.
	22 0	2	F	+ 4·4	+18·7	+17·1	Star-line seen well.
	24 0	2	F	+ 4·8	+25·3	+30·8	Star-line seen well.
	31 23	2	F	+ 6·3	+ 8·6	+ 5·9	Star-line seen fairly well.
June	27 23	2	F	+10·5	−10·9	− 6·3	Star-line seen fairly well.
July	3 22	2	F	+11·1	−16·6	−13·9	Star-line seen fairly well.
Aug.	6 22	2	F	+12·8	−78·4	−63·7	Spectrum faint and very unsteady. Star-line exceedingly ill-defined.
Sept.	8 21	2	F	+10·6	−26·9	−23·5	Star-line seen well.
				α Ophiuchi.			
Apr.	30 23	4	F	− 9·5	−17·4	−10·8	Star-line very broad and diffused.
May	15 23	4	F	− 6·4	− 9·9	− 7·3	Star-line very broad and diffused.
	22 0	2	F	− 5·0	− 6·1	− 7·9	Star-line seen fairly well.
	24 0	2	F	− 4·5	−13·3	−12·5	Star-line broad and diffused.
	31 24	2	F	− 2·6	−19·2	−17·7	Star-line seen fairly well.
June	7 0	2	F	− 1·2	−10·8	−10·2	Star-line seen fairly well.
	27 23	2	F	+ 3·8	−26·0	−20·6	Star-line seen well.
July	3 23	2	F	+ 5·2	−38·9	−36·0	Star-line unusually broad and diffused.
Aug.	1 22	2	F	+10·9	−46·3	−32·1	Definition poor.
	6 23	2	F	+11·6	−47·5	−43·4	Spectrum faint. Star-line ill-defined.
Sept.	8 22	2	F	+14·7	−35·1	−38·8	Star-line very ill-defined and difficult to observe.
				Vega.			
May	1 0	2	F	− 7·7	−30·8	−26·1	Star-line seen well.
	15 23	2	F	− 6·4	− 3·7	− 2·7	Star-line very broad and diffused.

Date. 1890. G.C.T.		No. of Meas.	Line.	Earth's Motion in miles per sec.	Concluded Motion of Star. Measd.	Estimd.	Remarks.
				Vega (continued).			
	d h						
May	22 1	2	F	− 5·8	−53·1	−51·3	Star-line seen well.
	24 0	2	F	− 5·6	−10·1	−12·3	Star-line seen well.
June	1 0	2	F	− 4·7	−25·5	−21·7	Star-line seen well.
July	3 23	2	F	− 0·3	−63·1	−46·3	Star-line seen well.
Aug.	1 23	2	F	+ 3·7	− 8·0	− 8·6	Star-line seen well.
	6 23	2	F	+ 4·3	−10·4	− 9·1	Star-line seen fairly well.
Sept.	8 22	2	F	+ 7·6	−26·0	−18·3	Spectrum bright but unsteady.
	13 21	2	F	+ 7·9	−24·6	−25·8	Star-line seen well.
	24 21	4	F	+ 8·5	−34·8	−34·4	Cloud passing.
Oct.	1 21	2	F	+ 8·7	−14·5	− 8·7	Definition bad.
	3 21	2	F	+ 8·7	−21·0	−23·5	Definition fair.
	9 20	2	F	+ 8·7	−45·0	−41·8	Star-line seen fairly well.
	11 21	2	F	+ 8·7	−41·5	−34·9	Definition bad.
	16 19	4	F	+ 8·6	−37·5	−31·6	Definition poor. Wind high.
				γ Lyræ.			
Aug.	1 23	2	F	+ 3·4	+ 7·5	+11·3	Star-line seen fairly well.
	6 23	2	F	+ 4·2	−16·2	−13·7	Star-line seen fairly well.
Sept.	13 21	2	F	+ 9·1	−29·8	−15·9	Spectrum extremely faint.
				ζ Aquilæ.			
Aug.	1 23	2	F	+ 5·2	− 7·7	− 5·2	Star-line seen fairly well.
	6 23	2	F	+ 6·3	−13·7	−11·1	Star-line seen with difficulty.
Sept.	13 21	2	F	+13·0	+10·4	+10·0	Spectrum extremely faint.
				δ Cygni.			
Aug.	7 0	2	F	0·0	−70·7	−52·5	Star-line faint and ill-defined.
Sept.	13 21	2	F	+ 4·6	+ 8·6	+22·6	Star-line seen fairly well.
				Altair.			
May	16 0	2	F	−14·2	− 5·2	− 1·8	Star-line seen well.
	24 0	2	F	−13·2	−20·7	−19·0	Star-line seen well.
June	1 0	2	F	−11·9	−10·0	− 8·4	Star-line seen well.
	28 0	2	F	− 6·3	−47·0	−27·2	Star-line seen well.
July	3 23	2	F	− 4·9	−57·4	−41·7	Star-line seen fairly well.
Aug.	1 22	2	F	+ 2·5	−45·2	−46·5	Star-line seen well.
	4 22	2	F	+ 3·3	−44·2	−39·2	Star-line seen fairly well.
	6 23	2	F	+ 3·8	−72·9	−70·6	Star-line seen fairly well.
Sept.	8 22	2	F	+11·4	−32·4	−30·1	Star-line seen well.
	13 22	2	F	+12·3	−30·8	−40·4	Star-line seen fairly well.

Date. 1890. G.C.T.		No. of Meas.	Line.	Earth's Motion in Miles per sec.	Concluded Motion of Star. Measd	Estimd.	Remarks.
				Altair (continued).			
	d h						
Oct.	1 22	2	F	+14·9	−35·3	−31·5	Definition bad.
	3 21	2	F	+15·1	−56·4	−51·3	Definition fair.
	9 21	2	F	+15·6	−44·0	−38·1	Star-line seen fairly well.
	11 21	2	F	+15·8	−76·6	−55·1	Definition bad.
	16 20	2	F	+16·1	−45·0	−37·6	Definition bad. Observations interrupted by cloud.
				γ Cygni.			
Oct.	11 21	2	F	+ 8·2	−51·2	−41·5	Definition bad.
				α Cygni.			
May	16 0	2	F	− 8·9	−51·2	−41·4	Star-line seen fairly well.
July	3 23	1	F	− 7·0	−42·4	−48·8	Observations interrupted by cloud.
Aug.	4 22	2	F	− 3·3	−64·8	−66·0	Star-line seen fairly well.
Sept.	8 23	2	F	+ 1·9	−47·8	−42·0	Spectrum bright and steady.
	13 22	2	F	+ 2·7	−28·5	−41·0	Spectrum fairly bright and steady.
Oct.	1 22	2	F	+ 5·3	− 4·7	− 5·3	Definition bad.
	3 22	2	F	+ 5·5	−36·6	−31·8	Star-line seen fairly well.
	9 21	2	F	+ 6·3	−42·3	−43·9	Star-line seen fairly well.
	11 21	2	F	+ 6·5	−33·9	−23·4	Definition poor.
				α Cephei.			
May	16 0	2	F	− 4·5	−38·1	−29·1	Star-line seen well.
Aug.	1 23	2	F	− 5·6	−87·8	−92·2	Star-line seen with the utmost difficulty.
Oct.	11 22	2	F	+ 0·8	−26·6	−19·9	Definition very bad.
	16 20	2	F	+ 1·4	−16·9	−16·1	Observing position very awkward.
				α Pegasi.			
Aug.	2 0	2	F	−11·3	−29·6	−27·8	Star-line seen fairly well.
	7 0	2	F	−10·0	−28·0	−25·8	Star-line seen fairly well.
Sept.	8 23	2	F	− 1·7	−21·9	−19·7	Star-line faint and seen with difficulty.
	11 23	2	F	− 0·9	−43·8	−47·5	Star-line seen well.
	13 22	4	F	− 0·3	+22·1	+20·3	Star-line seen fairly well.
Oct.	1 22	2	F	+ 5·0	−24·6	−23·0	Definition poor.
	9 21	2	F	+ 7·2	−19·5	−26·8	Star-line seen fairly well.
	11 22	2	F	+ 7·8	−27·4	−23·3	Definition poor.

Date. 1890. G.C.T.		No. of Meas.	Line.	Earth's Motion in Miles per sec.	Concluded Motion of Star. Measd.	Reduced.	Remarks.
	d h				*Mars.*		
May	31 23	2	F	...	− 2·0	0·0	Calculated motion −0·8.
June	7 0	2	F	...	− 6·1	0·0	Calculated motion +0·3.
					Great Nebula in Orion.		
Mar.	17 20	7	N_1	+ 16·2	− 7·4	...	Compared with Nitrogen. Observations too rough to give a satisfactory determination of displacement. Resulting wave-length of nebular line λ 5005·0, assuming that of the nitrogen as λ 5005·2.
					Moon.		
Mar.	3 22	5	F	...	− 2·3	...	The coincidence of the lines in the two spectra appeared perfect.
	28 23	5	F	...	− 2·4	...	
Apr.	30 22	5	F	...	+ 1·1	...	
May	5 22	5	F	...	+ 2·2	...	
	23 22	5	F	...	− 1·3	...	
	31 23	5	F	...	+ 1·7	...	
June	27 23	5	F	...	+ 1·2	...	
July	3 23	5	F	...	+ 2·6	...	
Aug.	2 0	5	F	...	+ 2·2	...	
	7 1	5	F	...	− 2·2	...	
					Sun.		
May	16 12	5	F	...	+ 1·1	...	The coincidence of the lines in the two spectra appeared perfect.
					Sky.		
Mar.	14 12	5	F	...	− 2·9	...	The coincidence of the lines in the two spectra appeared perfect.
	18 12	5	b_1	...	+ 1·0	...	
Sept.	10 12	5	F	...	+ 1·0	...	
	15 11	5	F	...	+ 3·5	...	
	17 12	5	b_1	...	− 8·6	...	The sky spectrum was found to be displaced towards the blue by a very small but unmistakable amount.

Observations of Occultations of Stars by the Moon and of Phenomena of Jupiter's Satellites, made at the Royal Observatory, Greenwich, in the year 1890.

(Communicated by the Astronomer Royal.)

Occultations of Stars by the Moon.

Day.	Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
1890 Jan. 15 (*a*)	Reapp. o^1 Libræ	Simms' No. 1	75	Dark	16 31 6·25	A. M.
Feb. 7 (*b*)	Disapp. ν Virginis	Lassell Refl.	280	Bright	11 6 7·08	L.
7 (*c*)	,, ν Virginis	E. Equat.	140	,,	11 6 6 12	H.
7	,, ν Virginis	Altaz.	100	,,	11 6 3·41	S. D.
7	Reapp. ν Virginis	,,	100	Dark	12 19 59·83	L.
7	,, ν Virginis	E. Equat.	140	,,	12 19 59·92	H.
Mar. 29 (*d*)	Disapp. 7 Cancri	Altaz.	100	,,	13 10 18·63	T.
Apr. 7 (*e*)	Reapp. ζ^1 Libræ	,,	100	,,	15 28 9·84	J. P.
7	,, ζ^1 Libræ	E. Equat.	70	,,	15 28 9·07	W.R.
30	Disapp. ν Virginis	E. Equat.	140	,,	10 58 12·83	H.
30	,, ν Virginis	Altaz.	100	,,	10 58 12·98	S. D.
30	Reapp. ν Virginis	,,	100	Bright	11 48 22·97	S. D
May 3	Disapp. 95 Virginis	E. Equat.	140	Dark	8 50 23·13	A. D.
3	,, κ Virginis	Altaz.	100	,,	13 7 31·36	H. T.
3	,, κ Virginis	E. Equat.	140	,,	13 7 31·36	A. D.
June 2 (*f*)	,, ω Ophiuchi	Altaz.	100	Bright	10 5 51·28	H. T.
2 (*g*)	,, ω Ophiuchi	E. Equat.	210	,,	10 5 54·96	A. D

Day.	Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
1890 June 29 (*i*)	Disapp. β^2 Scorpii	E. Equat.	60	Bright	9 59 37·12	L.
29	Reapp. β^2 Scorpii	,,	60	Dark	11 12 1·88	L.
29	,, β^1 Scorpii	,,	60	,,	11 12 3·98	L.
Sept. 6	,, Piazzi v. 192	,,	70	,,	12 41 58 48	W. R.
20	Disapp. 24 Ophiuchi	Altaz.	100	,,	7 54 31·36	J. P.
20	,, 24 Ophiuchi	E. Equat.	70	,,	7 54 31·14	A. D.
27 (*i*)	,, 30 Piscium	Altaz.	100	,,	10 36 9·98	H. F.
27 (*k*)	,, 33 Piscium	E. Equat.	140	,,	12 30 54·72	H.
Oct. 27 (*l*)	,, ξ^1 Ceti	Lassell Refl.	280	,,	7 22 33·00	H. T.
27	,, ξ^1 Ceti	E. Equat.	140	,,	7 22 33·64	H.
27 (*m*)	,, ξ^1 Ceti	Altaz.	100	,,	7 22 32·74	S. D.
27 (*n*)	Reapp. ξ^1 Ceti	E. Equat.	140	Bright	8 21 46·19	H.
27 (*o*)	,, ξ^1 Ceti	Altaz.	100	,,	8 21 (56·57)	S. D.

Notes.

(*a*) Cloudy.
(*b*) Star seemed to hang on limb for 1ˢ.
(*c*) Star appeared to *glide* behind Moon's limb; the disappearance had a perceptible duration; the time of last contact was noted.
(*d*) Star faint.
(*e*) Instantaneous.
(*f*) Clouds began to sweep over about 4ˢ before time of observation, but it is believed that the true occultation was observed, the star being close to the Moon's limb.
(*g*) Clouds passing.
(*i*) Cloudy; doubtful whether occulted by Moon or cloud.
(*k*) Moon's limb nearly full. Star did not seem to disappear instantaneously, but gradually faded away.
(*l*) Star disappeared into Moon's rough limb.
(*m*) Star very faint.
(*n*) Observation not considered good; perhaps late.
(*o*) Star some distance from Moon's limb when first seen.

Phenomena of Jupiter's Satellites.

Day.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1890 June 19	III.	Ecl. R. First seen	E. Equat.	210	12 43 57	12 44 19	H. T
19	III.	Occ. D. First contact	,,	,,	12 51 31	12 53	,,
19	III.	Last seen	,,	,,	12 55 45		,,
July 19 (*a*)	II.	Tr. Ing. First contact	,,	,,	12 12 40		W. R.
19	II.	Bisection	,,	,,	12 13 58	12 14	,,
19	II.	Last seen	,,	,,	12 16 6		,,
26	I.	Tr. Ing. First contact	Altaz.	100	9 17 29	9 21	L.
26	I.	Last seen	,,	,,	9 22 35		,,
26	III.	Tr. Egr. First seen	E. Equat.	140	11 35 50		,,
26	III.	Bisection	,,	,,	11 37 53	11 41	,,
26	III.	Last contact	,,	,,	11 40 14		,,
28	II.	Occ. R. First seen	Altaz.	100	11 36 4	11 37	S. D.
Aug. 1	III.	Occ. D. First contact	E. Equat.	60	8 52 51	8 55	T.
1	III.	Last seen	,,	,,	8 57 6		,,
1	III.	Ecl. R. First seen	,,	210	12 44 48		T.
1	III.	First seen	Altaz.	100	12 44 2	12 45 54	H. F.
1	III.	Full brightness	,,	,,	12 46 11		,,
1	I.	Occ. D. First contact	E. Equat.	210	13 54 11	13 56	T.
1	I.	Last seen	,,	,,	13 57 46		,,

Day.		Satellite.	Phenomenon.		Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N. L. h m s	Observer.
1850 Aug.	3 (b)	I.	Ecl. R.	First seen	E. Equat.	210	10 47 23	10 40 44	T.
	4 (c)	II.	Occ. D.	Last seen	"	"	10 55 46		H.
	4	II.		First contact	Altaz.	100	10 55 47	10 56	H. F.
	4	II.		Last seen	"	"	10 59 18		"
	18	I.	Tr. Ing.	First contact	E. Equat.	140	8 56 15		L.
	18	I.		Bisection	"	"	8 58 20	8 58	"
	18	I.		Last seen	"	"	9 0 36		"
	22 (a)	II.	Ecl. R.	First seen	"	210	8 31 40	8 33 38	T.
	29	III.	Ecl. R.	First seen	Altaz.	100	11 8 4	11 9 41	H. D.
	29	III.		First seen	E. Equat.	70	11 9 26		A. M.
Sept.	9 (d)	I.	Occ. D.	First contact	"	140	11 34 52	11 36	L.
	9	I.		Last seen	"	"	11 36 52		"
	10	I.	Tr. Ing.	First contact	"	70	8 41 2	8 44	H.
	10	I.		Last seen	"	"	8 44 46		"
	10	I.	Tr. Egr.	First seen	"	"	11 0 29	11 4	"
	10	I.		Last contact	"	"	11 7 48		"
	11	I.	Ecl. R.	First seen	"	"	9 20 23	9 19 40	H. F.
	12	II.	Occ. D.	First contact	"	210	11 27 36		A. D.
	12	II.		Bisection	"	"	11 29 40	11 31	"
	12	II.		Last seen	"	"	11 32 25		"

Day.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation.	Mean Solar Time of N.A.	Observer.
					h m s	h m s	
1890 Sept. 13	III.	Occ. R. First seen	Tr. Circle	195	8 48 57	8 51	L.
13 (*e*)	III.	Ecl. D. Last seen	E. Equat.	140	9 17 36	9 18 41	,,
19 (*f*)	I.	Tr. Egr. First contact	Altaz.	100	7 15 54	7 20	,,
20 (*g*)	III.	Occ. D. First contact	E. Equat.	210	8 35 59		A. D.
20	III.	Bisection	,,	,,	8 42 18	8 47	,,
20	III.	Last seen	,,	,,	8 48 22		,,
23 (*h*)	II.	Ecl. R. First seen	Lassell Refl.	280	8 20 14		L.
23 (*i*)	II.	Full brightness	,,	,,	8 21 51	8 18 11	,,
23 (*k*)	II.	First seen	E. Equat.	140	8 18 15		H.
23	II.	Full brightness	,,	,,	8 20 9		,,
24	IV.	Occ. R. Last contact	,,	,,	9 28 43	9 32	A. D.
24	IV.	Last contact	Altaz.	100	9 29 55		W. R.
25 (*l*)	I.	Occ. D. Last seen	E. Equat.	140	9 34 13	9 42	H.
27 (*h*)	I.	Ecl. R. First seen	,,	,,	7 39 17	7 39 4	,,
27	I.	Full brightness	,,	,,	7 41 33		,,
Oct. 3	I.	Tr. Ing. First contact	,,	,,	8 37 28		,,
3	I.	Bisection	,,	,,	8 41 38		,,
3	I.	Last seen	,,	,,	8 44 42	8 41	,,
3	I.	First contact	Altaz.	100	8 37 59		W. R.
3	I.	Last seen	,,	,,	8 45 38		,,

Day.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1890 Oct. 11	I.	Occ. D. First contact	Lassell Refl.	280	7 50 46		L.
11	I.	Last seen	,,	,,	7 55 1		,,
11 (*m*)	I.	First contact	E. Equat.	70	7 52 45	7 54	H. F.
11	I.	Bisection	,,	,,	7 54 16		,,
11	I.	Last seen	,,	,,	7 56 26		,,
12	I.	Tr. Egr. First seen	Lassell Refl.	280	7 19 25		A. D.
12	I.	Bisection	,,	,,	7 21 35	7 22	,,
12	I.	Last contact	,,	,,	7 23 40		,,
27	I.	Occ. D. First contact	,,	,,	6 10 7		H. T.
27	I.	Last seen	,,	,,	6 13 33	6 11	,,
27	I.	Last seen	E. Equat.	140	6 13 17		H.
28 (*n*)	I.	Tr. Egr. Last contact	,,	,,	5 43 10	5 41	L.
28 (*k*)	IV.	Ecl. R. First seen	,,	,,	8 36 16	8 41 40	,,
28	IV.	Full brightness	,,	,,	8 38 46		,,
Nov. 4 (*o*)	I.	Tr. Ing. First contact	Altaz.	100	5 15 16	5 17	W. R.
4	I.	Last seen	,,	,,	5 20 55		,,
5 (*k*)	I.	Ecl. R. First seen	Lassell Refl.	280	6 14 35	6 13 31	L.
5 (*p*)	I.	Full brightness	,,	,,	6 17 38		,,
5 (*q*)	IV.	Tr. Egr. Last contact	,,	,,	6 25 23	6 39	,,

Day.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1890 Nov. 17	I.	Tr. Ing. First contact	Altaz.	100	5 32 52		A. D.
17	I.	Bisection	,,	,,	5 39 21		,,
17	I.	Last seen	,,	,,	5 44 0		,,
17	I.	First contact	E. Equat.	70	5 37 45	5 35	H.
17	I.	Bisection	,,	,,	5 40 15		,,
17	I.	Last seen	,,	,,	5 42 54		,,

Notes.

(*a*) *Jupiter* very ill-defined. (*b*) Diffused. (*c*) Observation not considered good; power too high.

(*a*) Cloudy directly afterwards.

(*d*) Satellite scarcely visible, times necessarily rough. Last contact may have been really obscuration by cloud.

(*e*) Image bad; observation not considered good.

(*f*) Cloudy; observation very doubtful. (*g*) *Jupiter* very tremulous and ill-defined.

(*h*) Observation considered good. (*i*) Uncertain to quite 20ˢ. (*k*) Definition g od.

(*l*) Sky misty; satellite very faint; *Jupiter* ill-defined. The satellite seemed to merge in the limb at the time noted and was no more seen.

(*m*) Definition bad. (*n*) *Jupiter* very ill-defined; foggy. (*o*) Satellite faint; twilight. (*p*) Thin cloud, observation rough.

(*q*) The first contact was perhaps $6^h\ 19^m$ when the satellite was glimpsed for a few seconds. There can be no doubt about last contact. The satellite was followed till $6^h\ 45^m$; at $6^h\ 30^m$ it was right away from *Jupiter*.

The clear aperture of the mirror of the Lassell Reflector is 24 inches, of the object-glass of the Transit Circle 8·1 inches, of the E. Equatorial 6·7 inches, of the Altazimuth $3\frac{3}{4}$ inches, and of the Simms' No. 1, 3 6 inches.

The initials H. T., A. D., T., L., H., J. P., S. D., W. R., H. F., and A. M., are those of Mr. Turner, Mr. Downing, Mr. Thackeray, Mr. Lewis, Mr. Hollis, Mr. Power, Mr. Dolman, Mr. Russell, Mr. Furner, and Mr. Miskin respectively.

Royal Observatory, Greenwich:
1891 *January* 1.

Errata in Greenwich Observations of Comet a 1890 (*Brooks*).

(*Communicated by the Astronomer Royal.*)

Monthly Notices, vol. l. p. 528.

Greenwich Mean Solar Time of Observation, 1890.

	d	h	m	s		d	h	m	s
for Aug.	4	10	13	13 6	*read* Aug.	4	10	14	13
,,		10	21	9 0	,,		10	22	9
,,		10	29	4·3	,,		10	30	4
,,	15	10	25	41·0	,,	15	10	26	41
,,		10	28	24·1	,,		10	29	24
,,		10	32	28·6	,,		10	33	29

Monthly Notices, vol. li. p. 49.

Greenwich Mean Solar Time of Observation, 1890.

	d	h	m	s		d	h	m	s
for Sept.	14	8	22	58	*read* Sept.	14	8	23	48
,,		8	33	57	,,		8	34	37
,,		8	33	57	,,		8	34	37
,,	15	8	3	30	,,	15	8	4	29
,,		8	27	16	,,		8	28	16
,,		8	48	2	,,		8	49	2
,,		8	48	2	,,		8	49	2

The comparisons of the clock Earnshaw (by which the times of observation were recorded) with the Sidereal Standard Clock were found to be 1^m in error from 1890 July 2 to Sept. 22. A mistake of 1^m in the computed time of one of the observations on September 14 has also been found.

Royal Observatory, Greenwich:
1891 *January* 14.

Note on the Recent Determination of the Longitude of Paris.

By H. H. Turner, M.A., B.Sc.

In the year 1887 a request was made to the Astronomer Royal by the officers of the French Geodetic Survey that the longitude Paris-Greenwich should be redetermined with all the accuracy attainable by modern methods. This longitude was determined telegraphically under the direction of M. Le Verrier and Sir George Airy in 1854, both stars and signals being observed by the eye and ear method. The observers were M. Faye, of the Paris Observatory, and Mr. Dunkin, of the Greenwich Observatory, who were interchanged once. The instruments used were the large transit circles of the two observatories. The result found for the difference of longitude between the Greenwich transit-circle and the meridian of Cassini (Paris) was $9^m\ 20^s{\cdot}51$; and the accordance of the twelve nights of observation was remarkably good: it was quoted by Sir George Airy, in a letter to Sir John Herschel, as sufficient to justify the adoption of the final result, although this differed by about 1^s from the previously-assumed longitude, $9^m\ 21^s{\cdot}57$, determined by rocket signals in July, 1825. (*Phil. Trans.* 1826, Part II.)

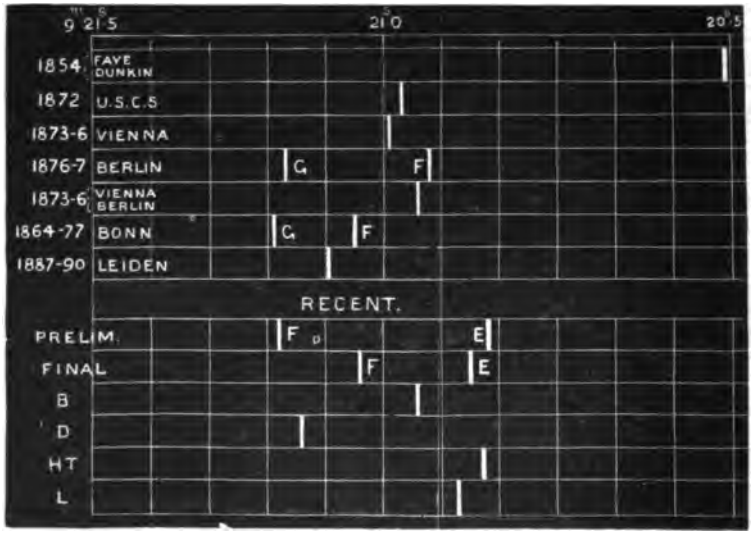
But there has since been reason to doubt the correctness of this result. In 1872 the same longitude was found by J. E. Hilgard, of the U.S. Coast Survey, to be $9^m\ 20^s{\cdot}97$ (U.S. Coast Survey: Report for 1872); and since then various indirect determinations (such as the combination of the longitude Vienna-Greenwich with Paris-Vienna) have indicated that the result of 1854 is too small. The following is a list of all telegraphic determinations published up to 1888:—

Longitude Paris (Cassini's meridian)—Greenwich (Transit Circle).

	Result.	Date.	Reference.
I. Direct.	m s		
Paris-Greenwich	9 20·51	1854	*Monthly Notices, R.A.S.* vol. xv. p. 124 (reduced to Cassini's meridian).
Paris-Greenwich	9 20·97	1872	U.S. Coast Survey, 1874, p. 180 (reduced to Cassini's meridian).
II. Indirect.			
Vienna-Greenwich	65 21·21	1876	Assoc. Géodésique. Report on Longitude, by Bruhns (1880).
Paris-Vienna	56 0·22	1873	
Paris-Greenwich	9 20·99		
Berlin-Greenwich	53 34·91	1876	Assoc. Géodés. (1883). Report by Bakhuyzen.
Paris-Berlin (F.)	44 13·99	1877	Comptes Rend. 1878, Feb. 4.
Paris-Greenwich (F.)	9 20·92		

	Result. m s	Date.	Reference.
Berlin-Greenwich	53 34·91	1876	*ut supra.*
Paris-Berlin (G.)	44 13·75	1877	Pub. Preuss. Geodät. Institut. 1877. p. 147.
Paris-Greenwich (G.)	9 21·16		
Vienna-Berlin	11 46·26	1876	Assoc. Géodés. (1883).
Berlin-Greenwich	53 34·91	1876	Assoc. Géodés (1883).
Paris-Vienna	−56 0·22	1873	*ut supra.*
Paris-Greenwich	9 20·95		
Bonn-Greenwich	28 23·31	1864	Assoc. Géodés. (1880).
Paris-Bonn (F.)	19 2·26	1877	Assoc. Géodés. (1880).
Paris-Greenwich (F.)	9 21·05		
Bonn-Greenwich	28 23·31	1864	
Paris-Bonn (G.)	19 2·12	1877	Pub. Pr. Geod. Inst. (1877)
Paris-Greenwich (G.)	9 21·19		
Greenwich-Leiden	17 56·30	1880	Assoc. Géodés. (1883).
Paris-Leiden	8 35·21		Provisional.
Paris-Greenwich	9 21·09		

The determinations Paris-Berlin and Paris-Bonn in 1877 were made independently by French and German observers, whose results are distinguished in the above table by the letters (F.) and (G.) A comprehensive view of these results is afforded by the upper portion of the subjoined diagram.



It is thus apparent that a direct redetermination of this longitude was a matter of great interest and importance. The Astronomer Royal accordingly entered into communication with the late General Perrier, then Director of the "Service Géographique de l'Armée Française," and with Admiral Mouchez, the Director of the Paris Observatory, as to the programme of observations and the date on which the operations could be commenced. It was decided that the summer of 1888 should be devoted to the work; and at this point negotiations were interrupted by the sudden and lamented death of General Perrier, on February 20, 1888. They were shortly afterwards renewed by Col. Derrècagaix, General Perrier's successor. It was arranged that M. Loewy (representing the Paris Observatory and the Bureau des Longitudes) and Commandants Bassot and Defforges (representing the Service Géographique) should pay a visit to Greenwich and settle the definitive programme in consultation with the Astronomer Royal. This visit was paid on June 15, 1888, and following days. M. Loewy reported that the Paris Observatory would not be able to take part in the work, which would thus be shared by the French Service Géographique and the Royal Observatory, Greenwich. It was decided that two observers should be appointed by each of these; and that the French observers should be Commt. Bassot (B) and Commt. Defforges (D); and the English Mr. Turner (H T) and Mr. Lewis (L). B and D were to use two French portable transit instruments by Brunner Bros., such as they had already used for other longitudes; and H T and L two of the portable transits by Troughton and Simms in the possession of the Greenwich Observatory. The observers were to be interchanged twice as follows:—

1st Series: 3 full nights, or the equivalent in half-nights.
D and L at Greenwich, B and H T at Paris.
2nd Series: 3 full nights, or equivalent.
B and H T at Greenwich, D and L at Paris.
3rd Series: 3 full nights, or equivalent.
B and H T at Greenwich, D and L at Paris.
4th Series: 3 full nights, or equivalent.
D and L at Greenwich, B and H T at Paris.

All four observers were to exchange signals automatically on their respective chronographs each night [in the order B and D, B and L, H T and L, H T and D for the 1st and 4th series, and the order D and B, D and H T, L and H T, L and B for the 2nd and 3rd series], so as to give 4 determinations of personal equation, two and two, and to eliminate small differences in the two chronographs at each station. Later in each complete evening the exchanges B—D and H T—L only were to be repeated, so that the mean epoch of these pairs of exchanges should be nearly the same as that of the time-determinations. The Paris station was at the Observatoire du Dépôt de la Guerre, Montsouris, where one French and one English instru-

ment were mounted on two piers 12 feet apart, the English instrument being to the east; and the Greenwich station the front court of the Royal Observatory, where two transit-huts were erected and two piers built, that for the French instrument being 41 feet, and that for the English instrument being 19 feet, west of the transit-circle. The four chronographs were kindly lent by the French Service Géographique, and had been in use for other longitude operations. A spare wire was courteously placed at the disposal of the Astronomer Royal each night from eight to twelve by the Submarine Telegraph Company; and the French and English Post Offices provided the services of clerks at Montsouris and Greenwich during these hours, and the use of wires from Paris to Calais and from Greenwich to London, so as to give direct communication between Montsouris and Greenwich. Operations were commenced on September 21, 1888, when Commt. Defforges arrived at Greenwich to co-operate in preparing the galvanic connections and to mount his instrument. Mr. Turner left for Paris on September 23. The following is an account of the course of the work, P denoting Paris and G Greenwich:—

September 25.—Cloudy P and G: exchange of practice signals.
September 26.—Cloudy P and G.
September 27.—Partly clear: instruments adjusted to meridian.
September 28.—Cloudy P and G.
September 29.—Cloudy P and G.
September 30.—Partly clear: one exchange: half-night.
October 1.—Partly clear: one exchange: half-night.
October 2.—Clear G: cloudy P.
October 3.—Partly clear: one exchange: half-night.
October 4.—Cloudy P and G.
October 5.—Quite clear P and G: two complete exchanges: full night.

(End of 1st Series.)

October 6.—HT returned to Greenwich. Clear G: cloudy P.
October 7.—D and L went to Paris. Clear G and P.
October 8.—B arrived at Greenwich. Clear G: raining P.
October 9.—Clear G: raining P.
October 10.—Cloudy P and G.
October 11.—Quite clear P and G: two exchanges: full night.
October 12.—Cloudy P and G.
October 13.—Clear P and G: two exchanges: full night.
October 14.—Clear P and G: two exchanges: full night.
October 15.—Clear P and G: trouble with batteries G: one exchange: half night.

(End of 2nd Series.)

October 16.—Cloudy P and G.
October 17.—Clear P and G: two exchanges: full night.
October 18.—Cloudy G: clear P.
October 19.—Clear P and G: two exchanges: full night.
October 20.—Clear G: only partly P: half night.
October 21.—Clear P and G: two exchanges: full night.

(End of 3rd Series.)

October 22.—B and H T went to Paris.
October 23.—D and L went to Greenwich: clear P: only partly G: half night.
October 24.—Cloudy P and G.
October 25.—Cloudy P and G.
October 26.—Cloudy P and G.
October 27.—Clear P and G: two exchanges: full night.
October 28.—Raining G: partly clear P.
October 29.—Raining G: partly clear P.
October 30.—Partly clear: one exchange: half night.
November 1.—Cloudy P and G.
November 2.—Cloudy P and G.
November 3.—Cloudy P and G.
November 4.—Cloudy P and G.
November 5.—Cloudy P and G.
November 6.—Cloudy P: clear G.
November 7.—Cloudy P and G.
November 8.—Cloudy P and G.
November 9.—Partly clear: one exchange: half night.
November 10.—Cloudy P and G.
November 11.—Cloudy P and G.
November 12.—Cloudy G: clear P.
November 13.—Clear P and G: two exchanges: full night.

(End of 4th Series.)

It was decided that the English observations and the French should be worked up and published separately; and the following account is chiefly confined to the English observations.

Instruments used, etc.

Transits B (at Paris) and C (at Greenwich) of the series used in Transit of *Venus* 1874. Clear aperture $3\frac{1}{2}$ inches, focal length $36\frac{1}{2}$ inches. The pivots were re-turned before the operations and found sensibly circular, and equal.

Clocks.

At Paris, Breguet No. 2, placed in the observing-room and subjected to considerable fluctuations of temperature.

At Greenwich, the Sidereal Standard, through the medium of two relays.

Instrumental Constants, etc.

Considerable labour was requisite to obtain a satisfactory determination of the values of the striding-level scales, which were found to be by no means uniform. A careful calibration, however, reduced the limits of possible error to very small amounts. The value of $1^{div.}$ ranged from $0''.73$ to $1''.35$ for the level of Transit B, and from $0''.92$ to $1''.57$ for that of Transit C.

Chronographs, etc.

The chronographs and the other automatic apparatus were of the pattern fully described in the "Mémorial du Dépôt Général de la Guerre," Tome XI., Section A, p. 20.

Instrumental Errors.

The collimation-error was determined both by reflexion observations from mercury and from observations of the same polar star in reversed positions of the instrument. No sensible systematic difference was found between the two methods for either instrument. [The actual mean systematic differences found for Transits B and C were $+ 0''.03$ and $- 0''.15$ respectively.] Some considerable trouble was caused at the beginning of the operations by the object-glasses almost simultaneously becoming loose in their cells. Trial observations with the instruments had been quite satisfactory. Fortunately, the discovery was made, and the defect remedied, before any actual longitude work had been done. Messrs. Troughton & Simms, to whom the instruments had previously been sent for examination, are unable to account for the occurrence.

The level error was determined both by reflexion observations and by the striding level. The systematic differences between the two methods were found to be $- 0''.13$ and $- 0''.28$ for B and C respectively.

The azimuth-error was determined by observation of one or more of 12 polar stars culminating between $19\frac{1}{2}^h$ and $3\frac{1}{4}^h$ sidereal time. It may be remarked that only one of the more frequently observed stars was observed at lower culmination: so that only 46 transits out of 262 were sub-polar. But though this may have some bearing on the absolute clock-errors at the two stations, it does not affect the longitude, the same stars (nearly) being observed at both stations. The places of the polar stars were adopted from recent Greenwich transit-circle observations.

Stars for Clock-error.

The stars were selected from a previously arranged catalogue, and the places adopted were corrected by means of the observations themselves, according to the method explained in the paper in "Mém. Gén. du Dép. de la Guerre" cited above. The mean of the corrections to ephemeris indicated by the results of all four observers was adopted for use.

Clock-rate.

The operations were arranged so that the mean epoch of the signals was as nearly as possible the same as the mean epoch of the star-transits on each night, and thus if the clock-rate be uniform during the operations on each evening, its magnitude has no sensible influence on the result for longitude. Moreover, the rate of the Greenwich clock was very small throughout, never reaching $0^s.2$ per day. But it was found that the rate of the clock used at Paris, which was subjected to considerable variations of temperature, was sensibly different at different times of the day. For the present investigation, the rate was assumed uniform for the period of observation on each night, and was determined independently by the English and French observers from comparison of the later star-transits with the earlier. The mean of their results was adopted for use; but the experience gained suggests the advisability of using a more carefully protected clock for longitude operations; for it is not at all clear that the assumption of a uniform rate from sunset to midnight (the usual period of observation for longitude work) for a clock known to have a diurnal inequality, is justifiable; and the above method of eliminating clock-rate by making coincident the mean epochs of signals and time-determination is not only sometimes difficult in practice, but is based entirely on this assumption of uniformity of rate.

Signals.

The exchanges of signals were made automatically, and the pairs of chronographs at each end were combined in the three possible different ways. The differences between different sets ranged over nearly $0^s.10$, this quantity being made up of errors resulting from changes in the state of the cable, in clock-rate, and others more or less accidental. As regards changes in the cable it may be remarked that the apparent time of transmission of the current deduced from comparison of signals sent in opposite directions, ranged from zero to $0^s.085$ for single sets of signals (40 each way in each set); or, if we compare the mean of different evenings, from $0^s.021$ to $0^s.067$.

Results for Longitude.

A preliminary discussion of the observations of the English and French observers, who made their computations independently, showed a considerable difference—about $0^s.4$—between their results for longitude. Such a large quantity as this was at first attributed to some mistake in computation, and all the figures were subjected to a careful scrutiny. But although one or two small matters were noticed which would diminish this difference (the discussion of which, however, belonged more properly to the final reduction), no serious mistake was discovered. It was then arranged that Commt. Defforges should visit Greenwich, bringing with him the French reductions, to discuss the discre-

pancy in concert with the English observers. This visit was paid in June, 1890. Another thorough examination of the reductions was made without result, but the discrepancy was localised in the time-determinations at Greenwich, where the English and French results were found to differ by a much larger quantity than the known difference of personal equations of the observers would explain. On further inquiry it was found that the results for level-error of the French instrument as obtained with the striding level differed systematically by 3″ from those obtained by reflexion observations from mercury. Only a few of the latter had unfortunately been made, but there could be no doubt about the discrepancy, which was confirmed in every case throughout the observations. The only difficulty was to explain this discrepancy on any assumption of instrumental defect. No satisfactory assumption has yet been thought of; but the fact remains that if the nadir observations were considered correct, and the striding-level observations consequently erroneous by the amount indicated, the French time-determinations would be brought into excellent accord with the English. In the absence of any direct confirmation of this view, however, the French observers did not feel justified in making this assumption; they decided rather to take the mean between the discrepant determinations of level-error; and consequently their results still differ from those of the English observers by half the amount in question—viz. about 0ˢ·16.

In the final discussion of the results there arises the question what weight shall be given to different nights. It is usual in such cases to make an elaborate determination of probable error for the various elements, and form weights accordingly; but in the present case a procedure was adopted which throws some light on the practical utility of such investigations—viz. various extreme suppositions were made in different directions, such as (1) that each evening should have equal weight whatever the number of observations; (2) that the weight should be directly proportional to the number of exchanges of signals, or (3) to the number of star-transits observed, &c. The first of these suppositions undoubtedly gives too much weight to the more unsatisfactory nights when little was done, and the second and third too much to the more complete nights. The truth should lie between them. But it was found that the results for longitude were practically the same on any of these suppositions, the whole range in such results being barely 0ˢ·01, and the mean of all is thus practically definitive. The following is the series of results obtained on eight of these different suppositions from the English observations:—

m	s	m	s
9	20·598	9	20·611
	·593		·599
	·594		·603
	·595		·605

It was thus not considered necessary to proceed further with the discussion of weights.

The final result for difference of longitude between the two instruments used by the English observers is $9^m\ 20^s{\cdot}60$, which, reduced to the meridian of Cassini and the Greenwich transit-circle, is

$$9^m\ 20^s{\cdot}85.*$$

The French reductions are practically complete, and their result will be $9^m\ 21^s{\cdot}04$ within a very small quantity. If the full correction to level indicated by nadir observations were adopted, this would be about $9^m\ 20^s{\cdot}88$, agreeing well with the English determination.

It may be remarked that the continuity of observations for time at Greenwich with the transit-circle, and with the same clock as was used by the longitude observers, affords a means of deducing the longitude from the observations of each observer independently. Thus the observations he made at Greenwich, when compared with those of the transit-circle, give his personal equation referred to the standard observer. On crossing to Paris, his time-determination can thus be directly compared, by means of the signals, with that made at Greenwich with the transit-circle. The results obtained in this manner would be as follows:—

			m	s
B	...	...	9	20·94
D	...	...		21·14
H T	...	...		20·83
L	...	...		20·87

It is to be remarked that the systematic correction to level-error from nadir observations was applied to the observations of B and D alike, although B did not make any nadir determinations. This may account for the discrepancy between their results.

* Transit C was 19 feet, or $0^s{\cdot}02$ W. of the Greenwich Transit-Circle; and Transit B was 12 feet, or $0^s{\cdot}01$ E. of the Montsouris meridian, which is $0^s{\cdot}29$ W. of the meridian of Cassini.

A List of Published Lunar Sketches and Photographs arranged according to the Sun's Position. By A. Marth.

In a paper published in vol. xlviii. of the *Monthly Notices*, containing my ephemeris for physical observations of the Moon, for the nine lunations from the middle of April to the end of 1888, I mentioned that I intended to examine all the lunar sketches in the library of the Royal Astronomical Society, and to prepare a properly-arranged list of those which deserve not to be left out, and which are at least approximately timed. The times required for the purpose are obviously the times when the outlines of the shadow are drawn. If these are properly recorded, it is easy, with the help of similar ephemerides and of some data in the list of sketches, to find (to about a minute) the corresponding times in other lunations, when the sun reaches the same zenith-distances at the sketched objects, and thus to connect the phenomena, in whatever lunation they may have been observed. If, instead of these times of drawing the shadows, only vague indications are given that the sketches have been made between such and such hours, the evidence supplied by the drawings is affected by a corresponding vagueness and weakened accordingly. An obvious difficulty arises, if the required times are not attached to the sketches themselves, but have to be searched for through pages of text, when they may perhaps be found mentioned merely by the way as apparently unimportant, or also may be searched for quite in vain. Some series of sketches have also to be disregarded, till it shall please the sketchers to state what times are those which they give.

The strangest fact, however, is, perhaps, that in the library of the Royal Astronomical Society there is a considerable number of lunar photographs, and that a number have also been published, without the slightest indication of the times when they were taken. The greater part of the valuable evidence which these photographs might furnish for the advance of selenography is thus practically lost. How is such unworkmanlike thoughtlessness to be accounted for?

Under the circumstances I give now only a portion of the intended general list of published sketches and photographs.

The first column, headed "Sun's Colongitude," and containing two terms, supplies, for any value of the Sun's selenographical latitude, the colongitude which the Sun must reach in order to be at the same altitude above the horizon of the sketched spot as at the assigned time of the sketch. By reference to the ephemeris the corresponding time may thus be found to about a minute.

Then follow the Sun's colongitude and latitude at the time of the sketch or photograph, the name of the spot, the assigned

time, the name of the sketcher and the references to the publications where the published sketches are to be found. The abbreviations employed are:—

E. M.: "English Mechanic." Vol. and page.
L'Astr.: Flammarion's publication, "L'Astronomie." Year and page.
L. S.: "Liverpool Astronomical Society Journal." Vol.
S. J.: The "Selenographical Journal." Vol.
Sir.: Klein's publication, "Sirius." Year.
Bianchini's sketch of Plato, made 1725 Aug. 16, one-and-a-half-hour after sunset at Rome, was originally published in "Hesperi et Phosphori nova phænomena," 1728, and has since been repeatedly reproduced.
Schmidt's sketches of Hyginus are to be found in "Sir." 1882.
Stuyvaert's 50 "Dessins de la Lune," in vols. 4 and 5 of the "Annales de l'Observ. R. de Bruxelles." For convenience the sketches are here numbered, 1–16 and 17–32 being those on two plates in vol. 4, and 33–50 in vol. 5.
Trouvelot's 15 sketches are to be found on plates 4, 15, 18, 20 in vol. 8 of the "Annals of the Astron. Observatory of Harvard College."
Weinek's sketches are in "Astron. Beobachtungen .. zu Prag im Jahre 1884, enthaltend Originalzeichnungen des Mondes," and in a second publication with a similar title containing the sketches made in the years 1885–87. The numbers attached are those on the published plates, so that the year must decide the volume. The times assigned are those of the beginning and ending of the sketching, it being stated that, with one exception, the middle time is to be considered as that of the shadows. But as the times are given in quarter-hours, inconvenient to print, they are left out in the list.
The meridians to which the assigned times refer are: Ath., Athens; Br., Brussels; C., Cambridge, Massachusetts; Gr., Greenwich, Pr., Prague.

Sun's Colongitude.		Sun's Colong. Lat.	Spot.	Assigned Time. References.
306°59 − 0·508	⊙'s lat.	306°40 + 0°38	Cleomedes	1888, Jan. 16, about 6h Gr. A. Mee, E M. 46, 50
310·40 − 0·686	„	310 00 + 0·58	Bernoulli	1883, Apr. 10, 3h 50m Br. Stuyvaert, 46.
320·73 + 0·162	„	320·81 + 0·48	Guttenberg	1881, Jan. 4, 6h 0m Br. Stuyvaert, 34.
321·59 + 0·162	„	321·74 + 0·92	„	1872, July 9, 9h 0m C. Trouvelot, pl. 15.
		326·78 + 0·75	Atlas, Hercules	1882, Apr. 22. 7h·5–9h·5 Gr. Elger, S.J. 5.
326·81 + 0·412	„	327·11 + 0·72	Fracastor	1886, Feb. 8, 6–7h. Goodacre, E.M. 42, 513.
329·61 + 0·036	„	329·61 + 0·33	Messier	1884, Mar. 31, 8h 15m Br. Stuyvaert, 49.
331·76 − 0·615	„	332·10 − 0·55	Posidonius	1879, Dec. 18, 5h 30m Br. „ 5.
333·61 + 0·075	„	333·50 − 1·52	Torricelli	1872, Mar. 14, 9h 30m C. Trouvelot, pl. 4.
336·09 + 0·077	„	336·20 + 1·47	„	1880, Mar. 16, 8h 20m Br. Stuyvaert, 7.
338·46 − 0·274	„	338·07 + 1·41	Plinius	1885, Jan. 21, 5h 30m Gr. Elger, L.S. 5.
339·83 − 1·122	„	341·07 − 1·12	Hercules	1887, June 26, ab. 8h 30m. A. Mee, E.M. 45, 437.
340·02 + 0·086	„	340·04 + 0·23	Hyputia	1872, June 11, 10h 0m C. Trouvelot, pl. 15.
341·22 + 0·625	„	341·41 + 0·31	Zagut...Lindenau	1884, Apr. 1. Weinek, 9.
341·72 − 0·274	„	342·01 − 1·05	Plinius	1873, Jan. 4, 6h 0m C. Trouvelot, pl. 18.
343·68 − 0·631	„	344·01 − 0·52	Posidonius	1879, Dec. 19, 5h 0m Br. Stuyvaert, 6.
345·29 − 0·155	„	345·54 − 1·52	Julius Cæsar	1872, Mar. 15, 9h 0m C. Trouvelot, pl. 15.
346·05 − 0·277	„	345·69 + 1·31	Plinius	1882, Jan. 25, 5–6h Gr. Elger, E.M. 50, 280.
346·73 − 1·195	„	347·99 − 1·05	Aristoteles	1880, Nov. 8, 6h 45m Br. Stuyvaert, 8.
348·19 − 3·098	„	346·54 + 0·53	Meton	1881, Jan. 6, 8h 45m Br. „ 36.

Sun's Colongitude.		Sun's Colong.	Lat.	Spot.	Assigned Time. References.
348°·86 − 0·088	⊙'s lat.	348°·73	+ 1°·48	Ariadaeus	1880, Mar. 17, 9ʰ 0ᵐ Br. Stuyvaert, 9.
		350·84	− 1·52	phot.	1890, Mar. 27, 8ʰ Paris. Henry.
351·59 − 0·528	,,	352·37	− 1·47	Linné	1873, Mar. 5, 7ʰ 0ᵐ C. Trouvelot, pl. 20.
351·89 − 0·283	,,	352·15	− 0·91	Plinius	1890, Jan. 27, 7ʰ Gr. T.S.S., E.M. 50, 528.
353·44 − 0·141	,,	353·53	− 0·63	Hyginus	1881, July 3, 7ʰ·7 Ath. Schmidt.
353·62 − 0·141	,,	353·78	− 1·48	,,	1880, Oct. 10, 6ʰ·0 Ath. ,,
354·51 − 0·141	,,	354·31	+ 1·41	,,	1879, Mar. 29, ab. 11ʰ Gr. Green, Neison, S.J. 2.
354·52 − 0·141	,,	354·39	+ 0·89	,,	1881, May 5, 7ʰ·2 Ath. Schmidt.
354·80 − 0·141	,,	354·59	+ 1·52	,,	1881, Mar. 7, 6ʰ·4 Ath. ,, S.J. 5.
355·13 − 0·141	,,	355·08	+ 0·36	,,	1880, June 14, 9ʰ 10ᵐ Br. Stuyvaert, 12.
355·64 − 0·141	,,	355·76	− 0·88	,,	1881, Oct. 29, 6ʰ 30ᵐ Br. ,, 44.
355·80 − 0·141	,,	356·02	− 1·53	,,	1881, Aug. 31, 7ʰ·0 Ath. Schmidt.
356·54 + 0·201	,,	356·82	+ 1·40	Albategnius	1886, Nov. 3. Weinek, 18.
356·66 − 0·141	,,	356 85	− 1·33	Hyginus	1878, Oct. 3, 5ʰ·6 Ath. Schmidt.
356·72 − 0·141	,,	356·73	− 0·05	,,	1878, Feb. 9, 5ʰ·7 Ath. ,,
356·78 + 0·072	,,	356·82	+ 1·40	Hipparchus	1886, Nov. 3. Weinek, 18.
356·95 − 0·141	,,	357·02	− 0·49	Hyginus	1879, Dec. 20, 6ʰ 40ᵐ Br. Stuyvaert, 13.
356·99 − 0·141	,,	356·86	+ 0·96	,,	1877, July 17, 9ʰ.5 Ath. Schmidt.
357·11 − 0·072	,,	357·22	− 1·52	Agrippa	1872, Mar. 16, 8ʰ 0ᵐ C. Trouvelot, pl. 4.
357·15 − 0·047	,,	,,	,,	Godin	,, ,, ,, ,,

Sun's Colongitude.		Sun's Colong.	Sun's Lat.	Spot.	Assigned Time. References.
°		°	°		
357·46 − 0·141	⊙'s lat.	357·28	+ 1·30	Hyginus	1882, Mar. 26, 8^{h} Gr. Green, S.J. 5.
357·54 − 0·141	,,	357·53	− 0·09	,,	1882, May 24, 8^{h} 30^{m}. McCance, S.J. 5.
357·66 − 0·141	,,	357·66	+ 0·02	,,	1878, Aug. 5, 7^{h}·5 Ath. Schmidt.
358·20 − 0·141	,,	358·02	+ 1·30	,,	1882, Mar. 26, 9^{h} 10^{m}–9^{h} 45^{m} Gr. Neison, S.J. 5.
358·23 − 0·141	,,	358·10	+ 0·92	,,	1879, Feb. 28, 6^{h}·7 Ath. Schmidt.
358·30 + 0·201	,,	358·20	− 0·49	Hipp., Albategnius	1879. Dec. 20, 9^{h} 0^{m} Br. Stuyvaert, 15.
358·47 − 0·141	,,	358·62	− 1·04	Hyginus	1880, Nov. 9, 5^{h}·0 Ath. Schmidt.
359·23 − 0·852	,,	358·83	+ 0·47	Cassini	1887, Jan. 31. Weinek, 19.
0·19 − 0·141	,,	359·97	+ 1·52	Hyginus	1879, Apr. 28, ab. 10^{h}·5 Gr. Green, S.J. 2.
0·46 − 0·142	,,	0·67	− 1·49	,,	1880, Sept. 11, 7^{h}·0 Ath. Schmidt.
0·70 − 0·142	,,	0·55	− 1·05	,,	1880, May 16, 8^{h} 30^{m} Gr. Green, S.J. 5.
0·78 − 0·142	,,	0·73	+ 0·36	,,	1880, Jan. 19, 4^{h} 20^{m} Gr. Rand Capron, S.J. 4.
0·95 − 0·142	,,	0·73	+ 1·52	,,	1879, Apr. 28, 12^{h} Gr. Neison, S.J. 2.
1·57 − 0·142	,,	1·77	− 1·38	,,	1881, Sept. 30, 6^{h}·5 Ath. Schmidt.
1·93 − 0·142	,,	1·72	+ 1·49	,,	1880, Mar. 18, 10^{h} 35^{m} Br. Stuyvaert, 14.
2·04 + 0·047	,,	2·11	+ 1·40	Réaumur	1881, Apr. 6, 9^{h} 0^{m} Br. ,, 40.
2·24 + 0·589	,,	1·35	− 1·51	Walter, Aliac., Werner	1884, June 30. Weinek, 13.
2·27 − 0·142	,,	2·49	− 1·54	Hyginus	1878, Nov. 2, 6^{h}·0 Ath. Schmidt.
3·11 + 0·151	,,	3·21	+ 0·66	Ptolemæus	1886, Feb. 11. Weinek, 10.
3·29 − 1·143	,,	3·18	+ 0·76	Hyginus	1878, July 7, 7^{h}·4 Ath. Schmidt.

Sun's Colongitude.	Sun's Colong. Lat.	Spot.	Assigned Time. References.
3°·34 − 0·858 ⊙'s lat.	2°·06 + 1'·49	Cassini	1830, Mar. 18, 11h 15m Br. Stuyvaert, 17.
	4·54 − 1·52	photo.	1890, Mar. 28, 9h Paris. Henry.
5·47 − 0·870 ,,	4·46 + 1·16	Cassini	1872, Oct. 9, 8h 0m C. Trouvelot, pl. 18.
6·05 − 1·047 ,,	6·31 − 0·25	Eudoxus	1877, Feb. 20, 10h C. ,, L'Ast. 85, 213.
6·39 − 1·620 ,,	5·97 + 0·26	Atlas	1884, Apr. 3, 7h 30m Gr. Elger, L.S. 2.
6·52 − 0·566 ,,	6·37 + 0·26	Archimedes	1884, Apr. 3. Weinek, 10; L'Ast. 87, 401.
6·84 + 0·231 ,,	6·58 − 1·09	Alphons, Alpetragius	1873, Jan. 6, 6h 30m C. Trouvelot, pl. 18.
6·94 + 0·328 ,,	,, ,,	Arzachel	,, ,, ,,
7·85 − 0·146 ,,	8·07 − 1·53	Hyginus	1881, Sept. 1, 6h·7 Ath. Schmidt.
8·02 − 0·320 ,,	7·81 + 0·67	Plinius	1889, Nov. 30, 8h 30m–9h Gr. Maw., E.M. 50, 340.
8·20 − 0·567 ,,	7·58 + 1·10	Archimedes	1880, Feb. 18, 8h 30m Br. Stuyvaert, 18.
8·30 − 0·156 ,,	8·17 + 0·86	Ukert	1881, May 6, 9h 0m Br. Stuyvaert, 41.
9·48 − 0·146 ,,	9·29 + 1·32	Hyginus	1878, June 8, 8h·5 Ath. Schmidt.
9·85 − 0·146 ,,	9·87 − 0·11	,,	1882, May 25, 8h 45m Gr. McCance, S.J. 5.
10·37 + 0·406 ,,	10·98 + 1·51	Wall near Thebit	1883, Feb. 15, 6h 30m. Elger, L.S. 5; E.M. 38, 496.
10·63 − 0·330 ,,	10·19 + 1·35	Plinius	1882, Jan. 27, 5h 30m–6h 15m. Elger, E.M. 50, 280.
10·69 − 0·147 ,,	10·76 − 0·47	Hyginus	1879, Dec. 21, 9h 30m Gr. Pratt, Sir. 80.
11·25 − 1·204 ,,	9·53 + 1·43	Plato	1725, Aug. 16. Bianchini. L'Ast. 87, 447.
11·80 − 1·018 ,,	11·34 + 0·45	Pico	1887, Feb. 1, 6h 0m Gr. Elger, L.S. 4; E.M. 44, 56
11·87 − 1·205 ,,	,, ,	Plato	,, ,, ,, ,, L'Ast. 87, 210

Sun's Colongitude.	Sun's Colong.	Lat.	Spot.	Assigned Time. References.
12°·39 + 0·234 ⊙'s lat.	12°·62	+ 0°·99	Alphons	1884, Mar. 5, 7h 30m. Elger, E.M. 39, 50.
13·51 + 0·182 ,,	13·58	+ 0·39	Guerike	1880, Jan. 20, 6h 0m Br. Stuyvaert, 19.
14·76 − 0·258 ,,	14·50	+ 1·01	Eratosthenes	1887, Dec. 23. Weinek, 23
	15·05	+ 1·23	photo.	1877, Apr. 21, ab. 10h Gr. Common, S.J. 3.
15·06 − 0·176 ,,	15·23	− 0·94	Stadius	1886, Apr. 12, 8h 0m Gr. Elger, E.M. 43, 214.
	15·14	+ 0·39	photo.	1880, Jan. 20, 8h 47m Gr. Common.
15·34 − 0·258 ,,	15·64	− 1·15	Eratosthenes	1872, Apr. 16, 9h 0m C. Trouvelot, pl. 4.
	16·21	+ 1·51	photo.	1890, Mar. 29, 8h Paris. Henry.
15·44 − 1·214 ,,	17·22	− 1·46	Plato	1873, Mar. 7, 8h 0m C. Trouvelot, pl. 20.
15·72 − 1·023 ,,	,,	,,	Pico	,, ,, ,,
17·25 + 0·182 ,,	17·18	− 0·40	Guerike, Parry	1887, Mar. 3, 7h 30m Gr. Elger, L.S. 6.
18·09 + 0·934 ,,	18·30	+ 0·23	Tycho	1884, Apr. 4. Weinek, 11.
18·82 + 0·073 ,,	18·73	− 1·12	Fra Mauro	1873, Jan. 7, 6h 30m C. Trouvelot, pl. 18.
18·93 + 0·182 ,,	,,	,,	Guerike, Parry	,, ,, ,,
19·43 + 0·141 ,,	19·40	− 0·24	Bonpland	1880, Dec. 10, 6h 0m Br. Stuyvaert, 20.
20·78 − 0·473 ,,	20·38	+ 0·84	Lambert	1881, May 7, 9h 0m Br. Stuyvaert, 42.
22·37 + 1·571 ,,	22·70	+ 0·21	Clavius	1886, Sept. 7. Weinek, 17.
24·72 + 0·546 ,,	24·71	− 0·02	Kies	1881, Nov. 20, 5h 15m Br. Stuyvaert, 45.
25·59 − 0·165 ,,	25·84	− 1·52	Copernicus	1884, July 2. Weinek, 14
	25·86	+ 0·42	,,	1876, Apr. 6, 9h–11h Gr. Brett, Obs. 1.

Sun's Colongitude.	Sun's Colong.	Lat.	Spot.	Assigned Time. References
26·17 + 0·294 ⊙'s lat.	25°·77	− 1°·37	Lubiniczki	18°·9, Mar. 11, ab. 7ʰ. G. T. Davis, E.M. 49, 109.
	27·73	+ 1·37	Alpine Valley	1885, Jan. 25, 6ʰ·5–8ʰ·5. Elger, L.S. 3; Sir. 85.
27·89 − 0·170 ,,	28·15	− 1·54	Hyginus	1878, Nov. 4, 7ʰ Gr. Lindsay and Copeland, M.N. 39.
28·98 + 0·523 ,,	28·68	− 0·57	Mersenius, Campanus	1886, Aug. 9, 8ʰ·5 Prag. Weinek, 16.
29·07 + 0·682 ,,	,,	,,	Cichus, Capuanus	,, ,, ,,
29·57 − 0·174 ,,	29·84	− 1·54	Hyginus	1878, Nov. 4, 10ʰ 20ᵐ. Lindsay and Copeland.
30·95 − 0·176 ,,	30·69	+ 1·45	Milichius	1880, Apr. 19, 8ʰ 20ᵐ Br. Stuyvaert, 22.
31·43 − 0·106 ,,	31·28	+ 1·45	Hortensius	1880, Apr. 19, 9ʰ 30ᵐ Br. Stuyvaert, 21.
31·61 − 0·057 ,,	31·60	+ 0·21	Reinhold	1884, Apr. 5, 9ʰ–11ʰ Gr. Elger, E.M. 39, 230.
32·03 + 0·126 ,,	31·85	− 1·43	Enclides, Riph.	1884, Aug. 1. Weinek, 16.
32·68 + 0·480 ,,	32·47	+ 0·82	Rills near Campanus	1881, May 8, 8ʰ 30ᵐ Gr. Elger, L.S. 5.
33·72 + 0·481 ,,	34·32	+ 1·25	,, ,,	1882, Mar. 29, 9ʰ. Elger, L.S. 5.
35·51 + 0·465 ,,	35·70	+ 0·41	Hippalus	1883, Apr. 17, 9ʰ 25ᵐ Br. Stuyvaert, 47.
35·72 + 0·329 ,,	36·22	+ 1·50	Agatharchides	1872, Sept. 12, 10ʰ 0ᵐ C. Trouvelot, pl. 15.
	35·94	+ 0·80	Sinus Iridum	1888, Dec. 23, 8ʰ 10ᵐ Gr. Elger, E.M. 48, 461.
	36·43	− 0·33	Newton, Short, Klaproth	1887, July 30. Weinek, 22.
36·72 − 1·343 ,,	36·17	+ 0·41	Condamine	1883, Apr. 17, 10ʰ 55ᵐ Br. Stuyvaert, 48.
36·82 − 0·001 ,,	36·82	− 1·83	Landsberg	1878, Oct. 6, 11ʰ Gr. Noble, S.J. 1.
37·98 − 0·136 ,,	38·01	− 0·23	Kepler	1890, Jan. 1, 11ʰ. T. S. S., E. M. 50, 528.
	38·30	− 1·53	Sinus Iridum	1884, July 3. Weinek, 15; L'Ast. 87, 401.

Sun's Co\ongitude.		Sun's Colong.	Lat.	Spot.	Assigned Time. References.
		38°·56	+ 1°·36	Mare Humorum	1881, Apr. 9, 8h 30m Gr. Elger, L.S. 5.
38·61	− 0·578 ⊙'s lat.	37·81	+ 1·37	Diophantus, Delisle	1885, Nov. 17. Weinek, 9.
39·63	− 0·578 ,,	39·61	+ 0·03	,, ,,	1885, Sept. 19, 7h 30m Gr. Elger, L.S. 5
39·65	− 0·075 ,,	39·75	− 1·34	Encke	1885, July 22. Weinek, 8.
40·98	+ 0·304 ,,	41·28	+ 0·99	Gassendi	1886, Oct. 8, 8h 15m Gr. Elger, L.S. 5.
41·30	+ 0·305 ,,	40·96	− 1·12	,,	1879, Nov. 24, 7h 0m Br. Stuyvaert, 23.
41·68	− 1·601 ,,	40·75	+ 0·58	Horrebow	1886, Feb. 14. Weinek, 11.
41·85	+ 0·532 ,,	42·53	+ 1·28	Doppelmayer	1884, Nov. 28, 7h–8h. Elger, L.S. 5.
42·94	+ 0·305 ,,	42·48	− 1·51	Gassendi	1887, May 3, 10h 30m–11h. J. Bone, E.M. 49, 368.
43·18	+ 0·305 ,,	43·23	+ 0·18	,,	1884, Apr. 6. Weinek, 12; L'Ast. 87, 401.
		43·54	+ 1·28	Alpine Valley	1884, Nov. 28, 9h–10h Gr. Goodacre, E.M. 40, 319.
44·18	− 0·138 ,,	44·37	− 1·42	Kepler	1884, Aug. 2. Weinek, 17; L'Ast. 87, 401.
44·16	− 0·076 ,,	,,	,,	Encke	,, ,, ,,
45·48	− 0·433 ,,	45·16	+ 0·75	Aristarchus	1885, Feb. 25. Weinek, 3.
49·04	+ 0·309 ,,	48·57	− 1·53	Gassendi	1873, Feb. 8, 8h 0m C. Trouvelot, pl. 20.
		49·08	− 0·40	Clefts near Mersenius	1883, Oct. 12, 7h–10h Gr. Elger, E.M. 38, 171.
49·78	+ 0·384 ,,	50·36	+ 1·52	Mersenius	1880, Mar. 22, 10h 30m Br. Stuyvaert, 25.
49·84	+ 0·309 ,,	50·30	+ 1·48	Gassendi	1886, Dec. 7, 5h 40m Gr. Elger, L.S. 5.
49·89	− 0·431 ,,	49·49	+ 0·92	Aristarchus, Herodotus	1884, Mar. 8, 7h 30m–9h 0m. Elger, L.S. 3.
50·07	+ 0·079 ,,	50·19	+ 1·52	Flamsteed	1880, Mar. 22, 10h 10m Br. Stuyvaert, 24.
50·66	− 0·585 ,,	50·12	+ 0·92	Wollaston	1884, Mar 8, 9h–10h Gr. Elger, E.M. 39, 485.

Sun's Colongitude.	Sun's Colong.	Lat.	Spot.	Assigned Time. References.
51°·91 + 0·385 ⊙'s lat.	51°·56	− 0°·92	Mersenius	1884, Sept. 1, 10h. Elger, L.S. 5.
	52·38	+ 1·53	Arist., Herodotus	1884, Jan. 9, 8h–11h Gr. Elger, E.M. 38, 448.
53·79 − 0·433 ,,	54·00	− 0·49	,, ,,	1887, Mar. 6. Weinek, 20.
53·87 − 0·433 ,,	54·38	− 1·18	,, ,,	1873, Jan. 3, 5h 0m C. Trouvelot, pl. 20.
55·00 + 0·388 ,,	55·20	+ 0·51	Mersenius	1887, Aug. 30. Weinek, 23.
	58·49	− 0·29	Herodot Valley	1886, Mar. 17, 8h 30m Gr. Elger, L.S. 5.
61·88 + 0·255 ,,	62·27	+ 1·53	Sirsalis	1880, Mar. 23, 10h 0m Br. Stuyvaert, 28.
62·23 + 1·159 ,,	60·55	− 1·45	Wargentin	1887, June 3, 9h 45m Gr. A. Mee, E.M. 45, 366.
62·31 + 0·255 ,,	62·44	+ 0·51	Billy, Hansteen	1880, Jan. 24, 6h 35m Br. Stuyvaert, 26.
62·89 + 0·093 ,,	62·84	− 0·58	Damoiseau	1880, July 19, 9h 15m Br. Stuyvaert, 27.
64·12 + 0·978 ,,	63·25	− 0·89	Schickard	1884, Sept. 2, 9h Gr. Elger, E.M. 40, 280.
64·41 + 0·093 ,,	64·49	+ 0·91	Damoiseau	1887, Dec. 27, 8h–9h. Elger, E.M. 47, 280.
64·62 − 0·116 ,,	64·71	+ 0·09	Reiner	1885, Sept. 21, 9h. Elger, L.S. 5.
67·93 + 0·991 ,,	69·34	+ 1·42	Schickard	1880, Apr. 22, 12h 30m Br. Stuyvaert, 29.
	70·58	+ 0·72	photo.	1877, Mar. 27, ab. 11h Gr. Common, S.J. 3.
	71·47	+ 1·42	Plinius	1882, Feb. 1, 7h. Elger, E.M. 50, 280.
80·89 + 0·108 ,,	81·04	+ 1·41	Grimaldi	1880, Apr. 23, 11h 35m Br. Stuyvaert, 30.
	83·10	+ 1·03	Plato	1887, Jan. 8, 12h 30m–14h. Williams, E.M. 44, 499. L'Ast. 87, 211.
84·18 − 1·837 ,,	81·60	+ 1·41	Cleostratus	1880, Apr. 23, 12h 40m Br. Stuyvaert, 32.
	84·91	− 0·21	Moon Eclipsed	1887, Aug. 3, 8h 37m Prag. Weinek.
	85·93	− 0·21	,, ,,	,, ,, 10h 38m Prag. Weinek.
	88·99	+ 1·35	λ − 69°, β + 80′	1881, Feb. 7, 9h 40m Br. Stuyvaert, 31.

Sun's Colongitude.		Sun's Colong. Lat.	Spot.	Assigned Time. References.
°		° ° 94·24 + 1·49	photo.	1875, June 18, 16h 9m sid. t. Cordoba. Gould.
99·84 + 0·751	⊙'s lat.	100·87 + 1·37	Gauss	1881, Feb. 14, 9h 10m Br. Stuyvaert, 37.
108·55 − 0·469	,,	108·08 + 0·99	Petavius	1890, Oct. 29, 9h 12m Gr. J. B., EM. 52, 334.
108·83 + 0·330	,,	108·45 − 1·14	Hyginus	1878, Dec. 10, 12h Gr. Lindsay and Copeland.
		112·53 − 0·69	Mare Crisium	1880, July 23, 11h 0m Br. Stuyvaert, 1.
113·49 + 0 663	,,	113·64 + 0·22	Geminus	1885, Sept. 25, 9h 30m Gr. Elger, E.M. 42, 299.
113·74 + 0·141	,,	113·94 + 1·39	Firmicus	1881, Feb. 15, 11h 0m. Br. Stuyvaert, 35.
114·80 − 0·188	,,	115·01 − 1·15	Gutt., Goclenius	1890, Feb. 6, 10h, ?Paris. Navarro, L'Ast. 90, 188.
118·18 + 0·329	,,	118·32 + 0·41	Plinius	1889, Dec. 9, 11h–11h 30m Gr. Maw, E.M. 50, 340.
118·28 + 0·757	,,	117·55 − 0·96	Messala	1883, Sept. 18, 11h Gr. Elger, L.S. 6.
121·50 + 0·508	,,	121·41 + 0·18	Cleomedes	1879, Dec. 30, 12h 40m Br. Stuyvaert, 3.
121·80 − 0·035	,,	121·83 − 0·91	Messier	1881, July 13, 14h 15m Br. Stuyvaert, 43; Sir. 84.
122·04 − 0·459	,,	122·52 − 1·05	Petavius	1886, June 18. Weinek, 16.
		125·58 + 0·66	Mare Crisium	1880, Jan. 29, 11h 30m Br. Stuyvaert, 2.
		125·83 + 0·76	,, ,,	1884, Mar. 14. Weinek, 5.
125·88 − 1·621	,,	126·30 − 0·26	Hagecius	1885, Apr. 2. Weinek, 4.
125·94 − 1·399	,,	126·30 − 0·26	Biela, Rosenberger	,, ,, ,, ,,
		126·00 + 0·66	Mare Fœcunditatis	1880, Jan. 29, 12h 20m Br. Stuyvaert. 4.
126·04 + 0·100	,,	126·06 + 0·25	Taruntius	1885, Sept. 26, 10h Gr. Elger, L.S. 5.
127 98 − 0·035	,,	127·93 + 1·40	Messier	1881, Feb. 16, 14h 40m Br. Stuyvaert, 38; Sir. 84.
130·69 + 0·377	,,	130·36 − 0·87	Macrobius	1887, July 8. Weinek, 21.

Sun's Colongitude.		Sun's Colong.	Sun's Lat.	Spot.	Assigned Time. References.
132°·18 − 0·241	⊙'s lat.	132°·50	− 1°·32	Colombo, Magelhaens	1884, Aug. 9. Weinek, 18.
132·20 − 0·607	,,	133·12	− 1·52	Neander	1886, May 21. ,, 14.
133·20 − 0·427	,,	133·38	− 0·44	Fracastor B.	1889, June 16, ab. 15^h Gr. J. M. Bacon, E.M. 49, 414.
134·16 − 0·908	,,	134·60	− 0·49	Fabricius, Metius	1886, Mar. 23. Weinek, 12.
134·90 + 2·251	,,	135·97	+ 0·48	Plato	1886, Sept. 16, 14^h 30^m Gr. Williams, E.M. 44, 151.
135·96 + 0·258	,,	135·76	− 0·76	Jansen	1880, Nov. 20, 11^h 15^m Br. Stuyvaert, 33.
137·47 + 1·052	,,	138·24	+ 0·73	Hercules	1884, Mar. 15. Weinek, 6.
138·60 − 0·905	,,	138·86	− 0·29	Fabricius	1885, Apr. 3. ,, 5.
139·74 + 0·178	,,	139·99	+ 1·42	Cauchy (Jansen A.)	1881, Feb. 17, 14^h 30^m Br. Stuyvaert, 39.
141·52 − 0·408	,,	141·89	− 0·91	Fracastor	1883, Sept. 20, 11^h Gr. Elger, L.S. 5; E.M. 38, 239.
142·45 + 0·282	,,	142·55	+ 0·35	Plinius	1889, Dec. 9, 10^h 30^m–11^h 50^m. Maw, E.M. 50, 340.
142·49 − 1·202	,,	144·05	− 1·30	Hommel, Pitiscus	1884, Aug. 10, 12^h 40^m Gr. Elger, L.S. 7.
144·14 − 0·407	,,	144·67	− 1·30	Fracastor	1884, Aug. 10. Weinek, 19; L'Ast., 87.
149·60 − 0·201	,,	149·46	+ 0·70	Theoph., Cyrillus	1884, Mar. 16. ,, 7.
151·56 + 0·615	,,	151·36	− 0·32	Posidonius	1885, Apr. 4. ,, 6.
153·76 + 0·274	,,	153·96	+ 0·73	Plinius	1887, Sept. 4, 11^h 0^m. Elger, E.M. 46, 109.
153·76 + 0·201	,,	153·52	+ 1·19	Cathar., Cyrillus	1885, Feb. 4. Weinek, 2.
153·91 − 0·326	,,	,,	,,	Theophilus	,, ,,
158·42 − 0·954	,,	158·50	− 0·08	Maurol., Barocius	1880, Jan. 2, 14^h 0^m Br. Stuyvaert, 10.
158·78 − 1·236	,,	159·45	− 0·54	Bacon	1886, Mar. 25. Weinek, 13.
158·86 − 1·092	,,	,,	,,	Clairaut, Barocius	,, ,,

Sun's Colongitude.		Sun's Colong.	Lat.	Spot.	Assigned Time. References.
162°·31 + 0·072	⊙'s lat.	162°·20	− 1°·54	Agrippa, Godin	1880, Sept. 24, 11^h 30^m Br. Stuyvaert, 11.
162·67 − 0·439	,,	163·32	− 1·48	Sacrobosco	1885, June 3. Weinek, 7.
163·08 − 0·947	,,	162·45	+ 0·67	Maurolycus	1884, Mar. 17. ,, 8.
164·49 + 0·142	,,	164·70	+ 1·49	Hyginus	1878, May 22, 15^h. Ath. Schmidt, Sir. 82.
		167·78	− 0·85	Clefts nr. Bradley	1883, Sept. 22, 13^h–15^h Gr. Elger, E.M. 38, 106.
		168·12	− 1·27	Alpine Valley	1884, Aug. 12, 11^h. Elger, L.S. 3; E.M. 40, 33; Sir. 85.
171·59 + 0·141	,,	171·38	− 1·49	Hyginus	1878, Oct. 17, 12^h 20^m. Lindsay and Copeland.
172·31 − 0·072	,,	172·34	− 0·40	Triesnecker	1878, Aug. 19, 13^h 0^m–14^h 20^m. Neison, S.J. 1.
172 47 + 0·141	,,	172·26	− 1·49	Hyginus	1878, Oct. 17, 13^h 40^m. Lindsay and Copeland.
172·66 − 0·201	,,	172·94	− 1·40	Albategnius	1879, Nov. 5, 13^h 45^m Br. Stuyvaert, 16.
172·81 + 0·141	,,	172·72	− 0·67	Hyginus	1880, Nov. 23, 13^h. Ath. Schmidt, Sir. 82.
173·07 + 0·141	,,	172·86	− 1·49	,,	1878, Oct. 17, 15^h 15^m Gr. Lindsay and Copeland, M.N., 39.
173·24 ,,	,,	173·03	,,	,,	,, 15^h 35^m ,, ,, ,,
173·62 ,,	,,	173·41	,,	,,	,, 16^h 20^m ,, ,, ,,
173·96 ,,	,,	173·96	,,	,,	,, 17^h ,, ,, ,,
186·94 − 0·932	,,	185·53	+ 1·51	Tycho	1885, Jan. 8. Weinek, 1.
187·17 + 1·230	,,	187·13	− 0·03	Plato	1883, Oct. 23, ab. 17^h. Gemmil. E.M. 38, 239.
187·22 + 1·230	,,	188·38	+ 0·94	,,	1884, Nov. 10. Weinek, 20; L'Ast. 87, 403.
1 7·40 − 0·406	,,	187·39	− 0·03	Wall nr. Thebit	1883, Oct. 23, 17^h 30^m. Elger, L.S. 5; E.M. 38, 496.
		209·44	+ 0·83	photo.	1876, Apr. 18, 18^h 54^m sid. t. Cordoba. Gould.

Ephemeris for Physical Observations of the Moon. By A. Marth.
1891 February 12 to May 5.

Greenwich Noon. 1891.	Selenographical Colong. of the Sun.	Lat. of the Sun.	Geocentric Libration. Sel. Long. of the Earth.	Lat. of the Earth.	Combined Amount.	Direction.
	°	°	°	°	°	′
Feb. 12	312·79	−1·45	+5·46	+5·70	7·88	316·4
13	324·98	1·46	6·66	4·69	8·14	305·3
14	337·16	1·47	7·36	3·45	8·12	295·2
15	349·33	−1·48	+7·59	+2·05	7·86	285·1
16	1·50	1·49	7·39	+0·58	7·42	274·5
17	13·66	1·50	6·85	−0·88	6·90	262·7
18	25·81	1·51	6·05	2·26	6·46	249·5
19	37·96	1·52	5·02	3·51	6·13	235·0
20	50·11	1·53	3·88	4·59	6·01	220·1
21	62·26	1·53	2·67	5·46	6·07	206·0
22	74·40	−1·54	+1·41	−6·08	6·24	193·0
23	86·54	1·54	+0·14	6·44	6·44	181·2
24	98·68	1·54	−1·12	6·51	6·61	170·3
25	110·82	1·55	2·37	6·31	6·70	159·4
26	122·97	1·55	3·58	5·82	6·83	148·5
27	135·12	1·55	4·72	5·08	6·93	137·2
28	147·27	1·54	5·77	4·09	7·07	125·5
Mar. 1	159·43	−1·54	−6·64	−2·90	7·25	113·7
2	171·59	1·54	7·34	1·56	7·50	102·0
3	183·76	1·53	7·73	−0·10	7·73	90·7
4	195·94	1·53	−7·75	+1·41	7·88	79·7
12	293·56	−1·49	+4·88	4·94	6·94	315·5
13	305·77	1·49	6·26	3·69	7·26	300·7
14	317·97	1·49	7·13	2·26	7·48	287·6
15	330·17	−1·48	+7·51	+0·74	7·54	275·6
16	342·36	1·48	7·41	−0·77	7·45	264·1
17	354·55	1·47	6·92	2·20	7·25	252·3
18	6·73	1·47	6·11	3·48	7·03	240·3
19	18·90	1·46	5·07	4·58	6·83	227·8
20	31·07	1·45	3·89	5·46	6·70	215·3
21	43·23	1·44	2·62	6·10	6·64	203·2
22	55·39	−1·43	1·33	−6·47	6·61	191·6
23	67·55	1·42	+0·05	6·56	6·56	180·4
24	79·71	1·41	−1·19	6·37	6·48	169·5
25	91·87	1·40	2·36	5·90	6·35	158·2

Greenwich Noon.	Selenographical. Colong. of the Sun.	Lat.	Geocentric Libration. Sel. Long. of the Earth.	Lat.	Combined Amount.	Direction.
1891.	°	°	°	°	°	°
Mar. 26	104·03	−1·38	−3·46	−5·15	6·20	146·2
27	116·19	1·37	4·46	4·17	6·10	133·2
28	128·35	1·35	5·34	2·98	6·11	119·2
29	140·51	−1·33	−6·07	1·63	6·28	105·1
30	152·68	1·32	6·61	−0·18	6·61	91·5
31	164·86	1·30	6·91	+1·32	7·03	79·2
Apr. 1	177·04	1·28	6·91	2·77	7·44	68·1
2	189·23	1·26	6·55	4·11	7·73	57·8
3	201·43	1·24	5·81	5·25	7 83	47 8
4	213·64	1·23	4·67	6·09	7·67	37·3
5	225·85	1·21	−3·18	6·57	7·29	25·7
11	299·20	−1·11	+6·24	+1·15	6·34	280·5
12	311·42	1·10	6·69	−0·44	6·71	266·2
13	323·64	1·08	6·70	1 96	6·98	253·6
14	335·85	1·07	6·31	3·34	7·14	242·0
15	348·06	1·05	5·59	4·52	7·18	230·9
16	0·26	1·03	4·61	5·46	7·15	220·1
17	12·45	1·01	3·46	6·15	7·06	209·3
18	24·64	0·99	2·21	6·57	6·93	198·5
19	36·83	−0·97	+0·93	−6·70	6·77	187·9
20	49·01	0·95	−0·33	6·55	6·56	177·1
21	61·19	0·92	1·52	6·11	6·30	166·1
22	73·36	0·90	2·60	5·39	5·99	154·3
23	85·53	0·87	3·55	4·42	5·67	141·3
24	97·70	0·85	4·35	3·23	5·41	126·7
25	109·88	0·82	4·98	1·86	5·31	110·5
26	122·06	−0·79	−5·42	−0·38	5·44	94·0
27	134·24	0·77	5·67	+1·15	5·78	78·5
28	146·42	0·74	5·69	2·64	6·27	65·0
29	158·61	0·71	5·47	4·02	6·78	53·6
30	170·81	0·69	4·98	5·19	7·19	43·7
May 1	183·01	0·66	4·23	6·09	7·41	34·7
2	195·22	0·63	3·22	6 63	7·37	25·8
3	207·44	0·61	1·99	6·77	7·05	16·3
4	219·67	0·59	−0·60	6·48	6·50	5·3
5	231·90	−0·56	+0·85	+5·77	5·83	351·6

Ephemeris of the Satellites of Uranus, 1891. By A. Marth.

Greenwich Noon. 1891.	P	*Ariel.* a_1	b_1	u_1-U	Diff.	*Umbriel.* a_2	b_2	u_2-U	Diff.
	°	"	"	°	°	"	"	°	°
Feb. 26	279·658	14·80	+10·37	37·62	1428·40	20·61	+14·45	251·45	868·68
Mar. 8	279·747	14·90	10·40	26·02	·36	20·76	14·49	40·13	·66
18	279·859	14·99	10·41	14·38	·33	20·89	14·50	188·79	·64
28	279·989	15·06	10·39	2·71	·30	20·98	14·48	337·43	·61
Apr. 7	280·131	15·11	10·35	351·01	·27	21·05	14·42	126·04	·60
17	·277	15·13	10·28	339·28	·24	21·08	14·32	274·64	·58
27	·421	15·12	10·20	327·52	·23	21·07	14·21	63·22	·58
May 7	·557	15·09	+10·10	315·75	·21	21·03	+14·06	211·80	·57
17	·681	15·04	9·99	303·96	·21	20·95	13·91	0·37	·57
27	·787	14·96	9·87	292·17	·20	20·84	13·75	148·94	·57
June 6	·871	14·86	9·76	280·37	·21	20·71	13·59	297·51	·58
16	·931	14·75	9·65	268·58	·21	20·55	13·44	86·01	·59
26	·965	14·63	9·54	256·79	·23	20·39	13·29	234·68	·61
July 6	·972	14·50	9·45	245·02	1428·24	20·21	13·16	29·29	868·62
16	280·952	14·37	+9·37	233·26		20·02	+13·05	171·91	

	Titania. a_3	b_3	u_3-U	Diff.	*Oberon.* a_4	b_4	u_4-U	U	B
	"	"	°	°	"	"	°	°	°
Feb. 26	33·81	+23·70	113·37	413·48	45·21	+31·69	43·71	358·499	+44·50
Mar. 8	34·05	23·77	166·85	·46	45·54	31·79	311·06	·563	44·27
18	34·26	23·79	220·31	·44	45·82	31·81	218·39	·644	43·97
28	34·42	23·75	273·75	·42	46·03	31·76	125·70	·737	43·62
Apr. 7	34·52	23·65	327·17	·42	46·17	31·62	33·00	·837	43·23
17	34·57	23·50	20·59	·41	46·23	31·42	300·30	358·940	42·82
27	34·56	23·30	74·00	·41	46·21	31·16	207·59	359·042	42·40
May 7	34·49	+23·07	127·41	·41	46·12	+30·85	114·88	·138	+41·99
17	34·36	22·82	180·82	·41	45·95	30·52	22·18	·224	41·61
27	34·18	22·56	234·23	·43	45·72	30·16	289·48	·297	41·28
June 6	33·97	22·29	287·66	·45	45·42	29·81	196·80	·355	41·01
16	33·71	22·04	341·11	·45	45·09	29·47	104·14	·395	40·81
26	33·44	21·80	34·56	·47	44·72	29·16	11·49	·416	40·69
July 6	33·14	21·59	88·03	413·49	44·32	28·88	278·86	·417	40·66
16	32·80	+21·42	141·52		43·92	28·65	186·24	359·420	40·71

The values of P, a, b, $u-\mathrm{U}$ are to be interpolated for the times for which the apparent positions of the satellites are required, and the position-angles p and distances s are then found by means of the formulæ:

$$s \sin (p-\mathrm{P}) = a \sin (u-\mathrm{U});$$
$$s \cos (p-\mathrm{P}) = b \cos (u-\mathrm{U}).$$

Titania and *Oberon* will appear in opposite directions from the centre of the planet:

Mar. 5 $13^{h}\cdot2$	Mar. 30 $4^{h}\cdot5$	Apr. 23 $19^{h}\cdot8$	May 18 $11^{h}\cdot1$	June 12 $2^{h}\cdot4$

and in the same direction

Mar. 17 $20^{h}\cdot8$	Apr. 11 $12^{h}\cdot1$	May 6 $3^{h}\cdot4$	May 30 $18^{h}\cdot8$	June 24 $10^{h}\cdot1$

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LI. FEBRUARY 13, 1891. No. 4

Lieut.-General J. F. TENNANT, C.I.E., R.E., F.R.S., President, in the Chair.

George Price Blackwood Hallowes, 77 Lansdowne Road, Didsbury, Manchester;
Shin Hirayama, Astronomer at Tokio Observatory, Japan;
Robert John Pearce, M.A., D.C.L., Professor of Mathematics in the University of Durham;
John Morris Stone, M.A., 29 Lee Park, Blackheath, S.E.

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:

John Billington Booth, J.P., Preston, Lancashire (proposed by Ralph Copeland);
Hannibal Mirabita, 134 Strada Britannica, Alexandria, Egypt (proposed by Rev. Joseph Reed).

REPORT OF THE COUNCIL TO THE SEVENTY-FIRST ANNUAL GENERAL MEETING OF THE SOCIETY.

The following table shows the progress and present state of the Society:—

	Compounders	Annual Subscribers	Mathematical Society	Total Fellows	Associates	Patron	Grand Total
December 31, 1889	234	358	3	595	48	1	644
Since elected	+5	+26	...	...	+3	...	...
Deceased	−4	−1	...	...	−3	...	...
Resigned	...	−4	...	...	...	...	...
Expelled	...	−1	...	...	...	...	...
Removals	+4	−4	...	...	...	...	...
December 31, 1890	239	374	3	616	48	1	665

Mr. Common's Account as Treasurer of the Royal

RECEIPTS.

	£	s.	d.	£	s.	d.
Balances, January 1, 1890:—						
at Bankers', as per Pass Book	488	18	7			
„ on Deposit Account	500	0	0			
in hand of Assistant Secretary on account of Turnor and Horrox Fund	4	13	5			
in hand of Assistant Secretary on Petty Cash Account	6	4	6			
				999	16	6
Dividends on £13,200 Consols, 2¾ per cent. ...	353	18	8			
Half years' Dividends on £750 Metropolitan Stock, 3 per cent.	10	19	6			
Half-years' Dividends on £1,250 Metropolitan Stock, 3 per cent.	18	5	8			
Interest on £500 on deposit at Bankers'	14	5	11			
				397	9	9
Received on account of Subscriptions:—						
Arrears	178	10	0			
257 Annual Contributions for 1890	539	14	0			
3 „ „ 1891	6	6	0			
30 Admission Fees	63	0	0			
26 First Contributions	40	19	0			
				828	9	0
8 Composition Fees				168	0	0
Sales of Publications:—						
At Williams and Norgate's, 1889	22	19	0			
At Society's Rooms, 1890	40	15	6			
				63	14	6

Audited and found correct, 1891 Jan. 6.

ARTHUR COTTAM,
ROBT. J. LECKY,
W. H. MAW.

£2,457 9 9

Astronomical Society, from January 1 to December 31, 1890.

EXPENDITURE.

	£	s.	d.	£	s.	d.
Assistant Secretary: Salary	250	0	0			
" " for assistance in editing Society's Publications ...	50	0	0			
				300	0	0
Income Tax and House Duty	10	10	0			
Fire Insurance	7	16	6			
				18	6	6
Printing, &c.	407	14	10			
Engraving, Lithography, &c.	44	16	6			
				452	11	4
Computation of Ephemerides	50	0	0			
Correction of Lunar Computations	3	3	0			
				53		0
Turnor and Horrox Fund: purchases for Library	8	12	8			
Binding Books in Library	48	7	4			
				57	0	0
Expenses of Eclipse Expeditions				65	7	3
Alterations and Fittings in Upper Library and Basement	249	12	0			
Carpet and Chairs in Upper Library, and Range in Kitchen	52	3	10			
Sundry Fittings and Repairs	6	4	4			
				308	0	2
Gold Medals				52	10	0
Purchase of Lunar Globe				1	1	0
House Expenses	32	17	7			
Wages	31	14	0			
Postage	82	10	9			
Carriage of Parcels	1	12	2			
Stationery and Office Expenses	9	3	10			
Brown Paper, &c., for repacking Stock	6	14	6			
Expenses of Meetings	20	0	0			
Coals and Gas	53	8	2			
Electric Lighting Expenses	11	4	9			
Time Signal: Rental of Wire	5	0	0			
Advertising	4	11	6			
Sundries	3	9	6			
				262	6	9
Mrs. Jackson Gwilt's Annuity	8	19	6			
Lee and Janson Fund Grants	12	10	0			
				21	9	0
Purchase of £500 Metropolitan 3 per cent. Stock at 102, including Commission				510	13	0
Cheque-book	0	8	4			
Bankers' Deductions on Cheques	0	3	6			
				0	11	10
Balances, December 31, 1890:—						
at Bankers', as per Pass Book	342	10	1			
Cheque not Credited till 1891	2	2	0			
in hand of Assistant Secretary on account of Turnor and Horrox Fund	6	0	9			
in hand of Assistant Secretary on Petty Cash Account	3	17	1			
				354	9	11
				£2,457	9	9

Assets and Present Property of the Society, January 1, 1891.

	£	s.	d.	£	s.	d.
Balances, December 31, 1890:—						
At Bankers', as per Pass Book	342	10	1			
Cheque not Credited till 1891	2	2	0			
In hand of Assistant Secretary on account of Turnor and Horrox Fund	6	0	9			
In hand of Assistant Secretary on Petty Cash Account	3	17	1			
				354	9	11
Due on account of Subscriptions:—						
1 Contribution of 5 years' standing	10	10	0			
4 Contributions of 4 ,, ...	33	12	0			
13 ,, 3 ,, ...	81	18	0			
31 ,, 2 ,, ...	130	4	0			
60 ,, 1 ,, ...	126	0	0			
3 Admission Fees and 1st Subscriptions	9	9	0			
	391	13	0			
Less 3 Contributions paid in advance ...	6	6	0			
				385	7	0
Due from Messrs. Williams and Norgate for sales of Publications during 1890				25	3	0
Due from Messrs. Wesley & Son, from sale of old non-astronomical books				18	18	1
£7,500 2¾ per Cent. Consols, including the Lee and Janson Fund, and the Turnor and Horrox Memorial Funds.						
£5,700 2¾ per Cent. Consols, including Mrs. Jackson Gwilt's gift (£300).						
£1,250 Metropolitan 3 per Cent. Stock.						
Astronomical and other Manuscripts, Books, Prints, Instruments, and Furniture.						
Unsold Publications of the Society.						
5 Gold Medals						

Report of the Auditors.

We have examined the Treasurer's accounts for the year 1890, and have found and certified the same to be correct. The cash in hand on Dec. 31, 1890, including the balance at the bankers', amounted to 354*l.* 9*s.* 11*d.*

The funded property of the Society has been increased by the purchase of 500*l.* Metropolitan 3 per cent. stock.

The books, instruments, and other effects have been examined, and they appear to be in a satisfactory condition.

We have laid on the table a list of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting, with the amount due against each Fellow's name.

ARTHUR COTTAM,
ROBT. J. LECKY,
W. H. MAW.

Stock in hand of volumes of the *Memoirs*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I. Part 1	7	...	XXX.	157	1
I. Part 2	42	...	XXXI.	140	...
II. Part 1	54	...	XXXII.	152	1
II. Part 2	20	...	XXXIII.	161	...
III. Part 1	65	1	XXXIV.	162	4
III. Part 2	84	1	XXXV.	107	5
IV. Part 1	77	3	XXXVI.	195	8
IV. Part 2	90	3	XXXVII. Part 1	337	8
V.	102	3	XXXVII. Part 2	283	8
VI.	123	3	XXXVIII.	268	1
VII.	146	3	XXXIX. Part 1	242	4
VIII.	126	3	XXXIX. Part 2	243	3
IX.	133	3	XL.	262	...
X.	146	...	XLI.	408	2
XI.	152	...	XLII.	232	3
XII.	159	...	XLIII.	235	2
XIII.	163	...	XLIV.	217	...
XIV.	366	2	XLV.	247	...
XV.	139	...	XLVI.	231	1
XVI.	163	...	XLVII. Part 1	3	...
XVII.	146	1	XLVII. Part 2	18	...
XVIII.	140	...	XLVII. Part 3	2	...
XIX.	147	...	XLVII. Part 4	10	...
XX.	141	...	XLVII. Part 5	10	...
XXI. Part 1	312	...	XLVII. Part 6	10	...
XXI. Part 2	98	...	XLVII.	214	1
XXI. 1 & 2 (together)	61	...	XLVIII. Part 1	253	3
XXII.	163	...	XLVIII. Part 2	263	2
XXIII.	147	...	XLIX. Part 1	485	2
XXIV.	155	...	XLIX. Part 2	247	4
XXV.	165	...	Index to *Memoirs*	644	...
XXVI.	171	...			
XXVII.	423	...			
XXVIII.	381	...			
XXIX.	403	1			

Stock in hand of volumes of the *Monthly Notices*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I.	64	...	XXVII.	4	...
II.	65	...	XXVIII.	72	...
III.	...	...	XXIX.	52	...
IV.	...	...	XXX.	65	2
V.	...	...	XXXI.	94	...
VI.	50	...	XXXII.	116	5
VII.	2	...	XXXIII.	98	1
VIII.	153	2	XXXIV.	75	1
IX.	24	3	XXXV.	58	...
X.	179	1	XXXVI.	31	1
XI.	184	1	XXXVII.	38	3
XII.	106	2	XXXVIII.	101	2
XIII.	178	3	XXXIX.	98	1
XIV.	177	3	XL.	112	3
XV.	169	2	XLI.	112	5
XVI.	154	2	XLII.	121	1
XVII.	167	1	XLIII.	121	...
XVIII.	245	...	XLIV.	124	3
XIX.	57	...	XLV.	123	2
XX.	34	...	XLVI.	118	2
XXI.	17	...	XLVII.	136	4
XXII.	33	...	XLVIII.	128	4
XXIII.	19	...	XLIX.	123	13
XXIV.	24	...	L.	125	16
XXV.	15	...	Index ...	565	3
XXVI.	11	...			

LIBRARY CATALOGUE 579

In addition to the above volumes of the *Monthly Notices*, the Society has a considerable stock of separate numbers of nearly all the volumes. With the exception, however, of Vols. XXXVI. to L. no complete volumes can be formed from the separate numbers in stock.

Instruments belonging to the Society.

No. 1. The *Harrison* clock.
„ 2. The *Owen* portable circles, by Jones.
„ 3. The *Beaufoy* circle.

No. 4. The *Beaufoy* transit instrument.
„ 5. The *Herschel* 7-foot telescope.
„ 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Utzschneider and Fraunhofer, of Munich.
„ 7. The *Smeaton* equatoreal.
„ 8. The *Cavendish* apparatus.
„ 9. The 7-foot Gregorian telescope (late Mr. Shearman's).
„ 10. The variation transit instrument (late Mr. Shearman's).
„ 11. The universal quadrat, by Abraham Sharp.
„ 12. The *Fuller* theodolite.
„ 13. The standard scale, by Troughton and Simms.
„ 14. The *Beaufoy* clock, No. 1.
„ 15. The *Beaufoy* clock, No. 2.
„ 16. The *Wollaston* telescope.
„ 17. The *Lee* circle.
„ 18. The *Sharpe* reflecting circle.
„ 19. The *Brisbane* circle.
„ 20. The *Baker* universal equatoreal.
„ 21. The *Reade* transit.
„ 22. The *Matthew* equatoreal, by Cooke.
„ 23. The *Matthew* transit instrument.
„ 24. The *South* transit instrument.
„ 25. A sextant, by Bird (formerly belonging to Captain Cook).
„ 26. A globe showing the precession of the equinoxes.
The *Sheepshanks* collection:—
„ 27. (1) 30-inch transit instrument, by Simms, with level and two iron stands.
„ 28. (2) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumbline; portable clamping foot and tripod stand.
„ 29. (3) Equatoreal stand and clock movement for $4\frac{6}{10}$-inch telescope (telescope lost); double-image micrometer; two wire micrometers; object-glass micrometer.
„ 30. (4) $3\frac{1}{4}$-inch achromatic telescope, with equatoreal stand; double-image micrometer; one terrestrial and three astronomical eyepieces.
„ 31. (5) $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.
„ 33. (7) 2-foot navy telescope.
„ 34. (8) Transit instrument of 45 inches focal length, with iron stand and also Ys for fixing to stone piers; two axis levels.
„ 35. (9) Repeating theodolite, by Ertel, with folding tripod stand.

No. 36. (10) 8-inch pillar sextant, by Troughton, divided on platinum, with counterpoise stand and artificial horizon.

„ 37. (11) Portable zenith telescope and stand, $2\frac{3}{4}$-inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, read to 10″ by two verniers to each circle.

„ 38. (12) 18-inch Borda repeating circle, by Troughton, $2\frac{1}{8}$-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.

„ 39. (13) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye-end, reading to single minutes; horizontal circle 9 inches diameter in brass, reading to single minutes.

„ 40. (14) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; heavy stand for theodolite; Y piece of level; two large and three small ground-glass bubbles divided; level collimator, object-glass $1\frac{5}{8}$-inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires; mercury bottle and trough.

„ 41. (15) Level collimator, with object-glass $1\frac{7}{8}$-inch diameter and 16 inches focal length; stand, rider-level, and fittings.

„ 42. (16) 10-inch reflecting circle by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon, with mercury; two tripod stands.

„ 43. (17) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. Circle divided on silver, reading to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.

„ 45. (19) 5-inch reflecting and repeating circle, by Lenoir, of Paris.

„ 46. (20) Reflecting circle, by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15″.

„ 47. (21) Box sextant; reflecting plane and level.

„ 48. (22) Prismatic compass, by Troughton and Simms.

„ 49. (23) Mountain barometer.

„ 50. (24) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.

No. 51. (25) Ordinary 4½-inch compass with needle.
„ 52. (26) Dipping needle, by Robinson.
„ 53. (27) Compass needle, mounted for variation.
„ 54. (28) Magnetic intensity needle, by Meyerstein, of Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.
„ 55. (29) Box of magnetic apparatus.
„ 56. (30) Hassler's reflecting circle, by Troughton; a 10½-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to 10″.
„ 57. (31) Box sextant and glass plane artificial horizon, by Troughton and Simms.
„ 58. (32) Plane 2⅜-inch speculum, artificial horizon, and stand.
„ 59. (33) 2½-inch circular level horizon, by Dollond.
„ 60. (34) Artificial horizon, roof, and trough; the trough 8¼ by 4½ inches; tripod stand.
„ 61. (35) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square; one beam compass.
„ 62. (36) A pantograph.
„ 63. (37) A noddy.
„ 64. (38) A small Galilean telescope with object-glass of rock crystal.
„ 65. (39) Five levels.
„ 66. (40) 18-inch celestial globe.
„ 67. (41) Varley stand for telescope.
„ 69. (43) Telescope, with object-glass of rock crystal.
„ 71. Portable altazimuth tripod.
„ 72. Four polarimeters.
„ 74. Registering spectroscope, with one large prism.
„ 76. Two five-prism direct-vision spectroscopes.
„ 78. 9½-inch silvered-glass reflector and stand, by Browning.
„ 79. Spectroscope.
„ 80. A small box, containing three square-headed Nicol's prisms; two Babinet's compensators; two double-image prisms; three Savarts; one positive eyepiece, with Nicol's prism; one dark wedge.
„ 81. A back-staff, or Davis' quadrant.
„ 82. A nocturnal or star dial.
„ 83. An early non-achromatic telescope, of about 3 feet focal length, in oak tube, by Samuel Scatliffe, London.
„ 84. A Hollis observing chair.
„ 85. Double image micrometer, by Troughton and Simms.
„ 86. 4½-inch Gregorian reflecting telescope, by Short,

with altazimuth stand and 6-inch altitude and azimuth circles and two eyepieces.

No. 87. 3¼-inch Gregorian reflecting telescope with wooden tripod stand.

„ 88. Pendulum, with 5-foot brass suspension rod, working on knife edges, by Thomas Jones.

„ 89. A Rhabdological Abacus. A contrivance invented by Mr. H. Goodwyn, consisting of a box filled with compartments, in which are square rods covered with numbers, which can be arranged so as to facilitate the labour of multiplying high numbers.

„ 90. An Arabic celestial globe of bronze, 5¾ inches in diameter.

„ 91. Astronomical time watchcase, by Professor Chevallier.

„ 92. 2-foot protractor, with two movable arms, and vernier.

„ 93. Beam compass, in box.

„ 94. 2-foot navigation scale.

„ 95. Stand for testing measures of length.

„ 96. Artificial planet and star, for testing the measurement of a fixed distance at different position-angles.

„ 97. 12-cell Leclanché battery.

„ 98. 2 feet 6 inch navy telescope, with object-glass 2½ inches, by Cooke, with portable wooden tripod stand.

„ 99. 12-inch transit instrument, by Fayrer and Son, with level and portable stand.

„ 100. 9-inch transit instrument, with level and iron stand.

„ 101. Small equatoreal sight instrument, by G. Adams, London.

„ 102. Sun-dial, by Troughton.

„ 103. Sun-dial, by Casella.

„ 104. Sun-dial.

„ 105. Box sextant, by Troughton and Simms.

„ 106. Prismatic compass, by Schmalcalder, London.

„ 107. Compass, by C. Earle, Melbourne.

„ 108. Prismatic compass, by Negretti and Zambra.

„ 109. Dipleidoscope, by E. Dent.

„ 110. Abney level, by Elliott.

„ 111. Pocket spectroscope, by Browning.

„ 112. Universal sun-dial.

„ 113. Double sextant, by Jones.

„ 114. Two models, illustrating the effects of circular motions.

„ 115. A cometarium.

No. 116. A pair of 18-inch globes.
„ 117, 118 } Two old sun-dials.
„ 119. Specimens of diffraction gratings, by Prof. W. A. Rogers.
„ 120. A 6-prism spectroscope, by Browning.
„ 121. Spitta's improved maximum and minimum thermometer.
„ 122. A 6-inch speculum, with flat; the speculum said to be by Sir W. Herschel, and re-figured by Sir J. Herschel.
„ 123. A 6-inch refracting telescope, by Grubb, with 3 eyepieces.
„ 124. Position micrometer, by Cooke.
„ 125. A 6-inch refracting telescope, by Simms, with eyepieces and solar diagonal.
„ 126. 3½-in. portable refracting telescope, by Tulley, with tripod stand.
„ 127. Globe representing the visible surface of the Moon, by John Russell, R.A. (1797).
„ 128. Bichromate battery and Ruhmkorff coil (presented by Mr. J. E. H. Peyton).

The following instruments are lent, during the pleasure of the Council, to the undermentioned persons:—

No. 4. The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.
„ 10. Variation transit, to Mr. Maxwell Hall.
„ 16. The *Wollaston* telescope, to Mr. R. Inwards.
„ 22. The *Matthew* equatoreal, to Mr. J. Brett.
„ 23. The *Matthew* transit, to Captain W. Noble.
„ 27. (1) 30-in. transit and one stand, to Mr. C. Thwaites.
„ 28. (2) 6-inch theodolite and stand, to Mr. A. A. Common.
„ 29. (3) Equatoreal mounting, clock movement, and pillar, to Mr. W. Peck.
„ „ Wire micrometer (No. 1), to Mr. C. Thwaites.
„ „ Wire micrometer (No. 2), to Mr. Maxwell Hall.
„ 30. (4) 3¼-inch equatoreal and stand, to Mr. E. B. Powell.
„ „ „ Double image micrometer, to Mr. Maxwell Hall.
„ 34. (8) Transit instrument and stand, to Professor C. Pritchard.
„ 38. (12) 18-inch *Borda* repeating circle, to Mr. Maxwell Hall.
„ 39. (13) 8-inch repeating circle, to Mr. J. Norman Lockyer.
„ 42. (16) Artificial horizon, roof, and mercury bottle, to Mr. C. Thwaites.
„ 50. (24) Prismatic compass, to Mr. Maxwell Hall.

No. 52. (26) Dipping needle, to Mr. Maxwell Hall.
„ 54. (28) Magnetic intensity needle, to Mr. Maxwell Hall.
„ 69. (43) Telescope, with rock-crystal object-glass, to Dr. W. Huggins.
„ 78. 9¼-inch reflector and stand, to Mr. Maxwell Hall.
„ 79. Spectroscope, to Mr. Maxwell Hall.
„ 86. 4½-inch Gregorian reflector by Short (two mirrors only), to Mr. A. A. Common.
„ 125. 6-in. refractor by Simms, to the Rev. A. Freeman.

The Gold Medal.

No Gold Medal has been awarded by the Council this year.

Obituary.

The Council regret that they have to record the loss by death of the following Fellows and Associates during the past year:—

Fellows:—Wentworth Erck.
General Edward Frome.
W. J. Ibbetson.
Harry Taylor.
Rev. Alfred Weld.

Associates:—C. H. F. Peters.
O. A. Rosenberger.
Herman Schultz.

Wentworth Erck was born in Dublin in 1827, and was the eldest son of John Caillard Erck, of Huguenot descent, an Ecclesiastical Commissioner for Ireland. His prænomen he derived by right of his grandmother, Elizabeth Wentworth, niece of Sir John Wentworth, baronet, Lieut.-Governor of Nova Scotia in 1808. Educated in part at Rugby, he graduated at Trinity College, Dublin, in 1850, and was in the same year called to the Irish Bar. In 1859 he took the degree of LL.D. Chemistry and mechanics had been the pastimes of his boyhood, and while still a youth he developed the predilection for astronomy which distinguished him through life. On his marriage, the better to discharge his duties to his tenantry he chose for his residence "Sherrington," not far from his landed property in the county Wicklow. He there erected an observatory, of which, and of his investigations, the following account has been kindly supplied by Mr. Arthur A. Rambaut, Assistant-Astronomer at Dunsink:—

"Dr. Erck's observatory, as well as a great many details in the construction of his instruments, was designed by himself to suit his special requirements. The object-glass of his equatoreal was a $7\frac{1}{2}$-inch, by Alvan Clark, which had formerly belonged to the late Mr. Dawes, and with which much of the earlier work of that distinguished observer had been accomplished. It is in

some respects a remarkable glass, being so full of bubbles that to one versed in such matters it might have appeared almost worthless for the delicate purpose for which it was intended; whereas it is remarkable for the exquisite definition it is capable of affording, as was proved on more than one occasion by the work done with it in the hands of Mr. Dawes and Dr. Erck.

"Within the last few years he obtained an important addition to his instrumental equipment in a fine silver-on-glass reflector of 15 inches aperture, for which he designed an alt-azimuth mounting, completed a little before his death.

"From the commencement of his career as an observer he paid especial attention to the appearance of the Sun's disc, and has left a record of the appearance of its surface on a large number of days in each year from 1869 up till 1888. In the earlier years of this period he contented himself with a general description of the appearance and position of the spots and faculæ from day to day, with occasionally a pen-and-ink sketch of the more remarkable forms. About the middle of this period, however, he had a reticule of glass, with small squares ruled on it, inserted in the focus of his telescope, with which he was enabled to determine the positions of the markings with sufficient accuracy for the purpose of identification.

"He spent a portion of nearly every year in London, and in order to continue unbroken his series of solar observations, he was in the habit of taking with him a small telescope of $3\frac{1}{2}$ inches aperture, with which he was enabled, by means of a portable equatoreal mounting, described by him in the pages of the *Monthly Notices*, to carry on his solar work.

"But although his observations of the Sun occupied a large part of his attention, they by no means exhausted it. He took a keen interest in almost all branches of observational astronomy. His most sustained labours, next to the series of his solar observations, were devoted to some double stars which were known or suspected to constitute binary systems. In this connection he devoted himself entirely to measuring position angles, leaving the determination of distance to those possessing telescopes of larger aperture. His attention was principally directed to some forty selected binaries, of which he obtained more than 1,900 measurements between the years 1873 and 1880, during which period he seems to have been most active as an observer.

"From time to time, as they appeared, Dr. Erck observed and recorded the appearance of the brighter comets, and was in the habit of sending occasional notices of such events to the local papers, as well as to the scientific periodicals.

"He paid a good deal of attention to the faint comites of some of the brighter stars, such as *Sirius*, *Procyon*, and *Rigel*; and at the opposition of *Mars* in 1877 he distinguished himself as one of the very few observers in this country who were able to pick up the satellites of that planet, which had been lately discovered by Professor Asaph Hall with the great 26-inch

achromatic at Washington—a remarkable feat for so small a telescope, and one requiring a keen-sighted observer at the eye-end.

"Among other phenomena which engaged the attention of Dr. Erck was the appearance of *Jupiter's* surface in the year 1880, at which time the red spot was very conspicuous. He appears to have been one of the first, if not the very first, to notice the proper motion of this spot with regard to the general surface of the planet. The appearance of *Saturn's* rings and the comparative brightness of his satellites also engaged a good deal of his attention from time to time, although he does not appear to have published the results of these observations. Indeed, his published works bear a very small proportion to the extent of his labours, and, to judge exclusively by this standard, one would form a most inadequate estimate of his astronomical activity. Those who have known him, however, will not lightly forget his zeal and enthusiasm, and the interest he took in all questions touching his favourite science, or the hearty manner and ready hospitality which made a visit to the Sherrington Observatory so memorable and agreeable."

Dr. Wentworth Erck contributed several papers to the *Monthly Notices* on observational astronomy and instrumental appliances.

Dr. Erck's devotion to science was not allowed to interfere with the discharge of his duties as a Poor-Law guardian, a magistrate, and a country gentleman. He was at one time invited to stand for Parliament in the Conservative interest, but declined. That the energy he displayed in his public duties used up his capital of health and shortened his life there can be little doubt; but his appetite for work was keen and his spirit indomitable, and he always expressed the desire, which was granted him, to "die in harness." His unfailing good temper, his child-like heart, his simplicity of character, and his perfect contentment attracted to him a wide feeling of respect.

His death took place at his residence on January 15 of the past year.

He was elected a Fellow of this Society March 9, 1855.

Edward Charles Frome was born at Gibraltar on January 7, 1802. He was the son of the Rev. J. T. Frome, a member of a well-known Dorsetshire family. He was educated first at a school at Bexley, afterwards at a school at Blackheath, where he was a schoolfellow of Benjamin Disraeli. In his fifteenth year he entered the Royal Military Academy at Woolwich, where he studied engineering under Olinthus Gregory and Peter Barlow, and attended the science lectures of Faraday. He distinguished himself in all his examinations, and passed out for his commission at the head of his batch. There were at that time no vacancies in the Royal Engineers, and it was not

till the year 1825 that he was gazetted second lieutenant in this branch of the service.

Early in his career, in 1827, he was ordered to Canada, where he made the whole of the surveys for the Rideau Canal, connecting the Ottawa River with Kingston on Lake Ontario. The construction of the main part of this important work he superintended until its completion.

In 1835 he succeeded Lieutenant, afterwards Sir William Denison, at Chatham as Instructor in Surveying and Practical Astronomy. At this time he published his work entitled "An Outline of the Method of Conducting a Trigonometrical Survey."

In 1839 Lieutenant Frome was offered the post of Surveyor-General of the Colony of South Australia. He accepted the appointment on condition that he should have the sole control of the work. At this time the work of the survey was lamentably in arrear, and the greatest confusion existed as to the boundaries of land. Captain Frome, who had been promoted soon after his arrival in the colony, undertook, as his first work, a thorough system of triangulation, afterwards employing a staff of some 400 men, in independent surveying parties of 10 men each, to fill in the details. The result of this organisation was, that in a comparatively short time the work of the survey was brought well in advance of the requirements of the Land Commissioners, and the cost greatly reduced.

It was for the use of these independent surveying parties that Captain Frome published his pamphlet of "Instructions for the Interior Survey of South Australia," which was afterwards incorporated in the later edition of his work on "Trigonometrical Surveying." This has long been a standard work, and a fourth edition of it, greatly enlarged, and edited by Sir Charles Warren, has recently appeared. For ten years Captain Frome was engaged in surveys which embraced all the then known parts of South Australia, and in addition a considerable portion which he was the first to explore. He returned to England in 1849. In 1851 he was appointed Surveyor-General of Mauritius—an appointment which he held until 1858, when he returned home. In 1863 Colonel Frome went out as Commanding Royal Engineer to Gibraltar, and in 1868 he succeeded Sir John Burgoyne as Inspector-General of Fortifications and Inspector of the corps of Royal Engineers. Subsequently he was appointed Lieutenant-Governor of Guernsey, which post he held for five years.

General Frome throughout his long life took the keenest interest in everything connected with engineering. Whatever he undertook he did thoroughly and well. He was a man of a high tone of mind, the first principle which guided his life being the call of duty. He was modest and unassuming in character and was honoured and respected by all who knew or had served under him. When he died on February 12, 1890, he was at the head of his corps, of which he was the senior Colonel Commandant.

General Frome was an Associate of the Institution of Civil Engineers for fifty-two years. He was elected a Fellow of this Society May 11, 1838.

HARRY TAYLOR was born at Bocking, in the County of Essex, on May 29, 1831. He was a descendant of an old Huntingdonshire family which formerly bore the name of Taylard. Mr. Taylor received his education at Mr. Malleson's school at Hove, and at University College, London. He took much interest in astronomy, but did not devote himself to any special research. As a business man he was extremely shrewd and clever, and possessed faculties that were of high value to the firm of which he was a member. He died April 27, 1890, after a short illness.

He was elected a Fellow of this Society November 10, 1871.

ALFRED WELD was born on August 5, 1823. He was the son of Mr. George Weld, of Seagrave, and grandson of Mr. Thomas Weld, of Lulworth—a well-known county family. He was educated at Stonyhurst, where he took a prominent place. In 1842 he entered the Society of Jesus, and in 1847 graduated at the London University. In 1848 he took charge of the meteorological observatory at Stonyhurst, in which position he continued for three years.

During this period, in 1848, the late Father Secchi, who was then a theological student, came to Stonyhurst in consequence of the expulsion of the Jesuits from Rome. Father Weld showed him round the Observatory, and interested him so much in the work that there are some grounds for believing Secchi was thereby induced to devote himself to astronomy. There is a tradition at Stonyhurst that Secchi's first astronomical observations were made with the 4-inch equatoreal of that Observatory.

In 1851 Father Weld retired from scientific work in order to devote himself to theological studies. He was ordained in 1854, and resumed charge of the Observatory in 1857.

In the magnetic survey of Great Britain, undertaken by Sir Edward Sabine in 1858, Father Weld was much interested; and having purchased a set of instruments, he inaugurated that series of magnetic observations which has been carried on uninterruptedly at Stonyhurst Observatory to the present time. At this period also he organised the astronomical work of the College.

In 1860 Father Weld resigned charge of the Observatory, and was succeeded by the late Father Perry.

In 1864 he was made Provincial of the English Province of the Society of Jesus, and in that position did much to aid and encourage the work at the Stonyhurst Observatory. In 1871 he was appointed Rector of the theological college of St. Beuno. In 1873 he became assistant to the Father-General of the Society

of Jesus, and finally, in 1884, he was made Superior of the Mission on the Zambesi. He died at St. Aidan's College, Grahamstown, on July 24 of the past year.

Father Weld was a man of exceedingly polished manners, and distinguished by great energy and tact in the conduct of business. He was twice employed by His Holiness Pope Leo XIII. in the management of delicate affairs, in which he succeeded admirably. How bravely he bore himself at Gibraltar under the savage attack of a mob of roughs is well known. He never lost his interest in science. When Provincial he gave Father Perry all possible encouragement. When Superior of the Zambesi Mission he set up a Stevenson screen and meteorological instruments at St. Aidan's College. Moreover, he purchased a set of instruments for observing the magnetic elements, and sent an assistant to M. d'Abbadie to be trained in their use, so that he might make magnetic observations in his missionary journeys. Unfortunately, the instruments becoming damaged, without means of getting them repaired, the attempt was rendered abortive.

Father Weld published a few communications in Vol. XI. of the *Monthly Notices*. He contributed several articles on scientific subjects to the *Month*, and he was the author of an extensive historical work on the suppression of the Jesuits in Portugal.

He was elected a Fellow of this Society January 12, 1849.

Christian Heinrich Friedrich Peters was born on September 19, 1813, at Coldenbüttel, in the province of Schleswig, where his father, Hartwig Peters, was a minister. He received his early education, from 1825 to 1832, at the Gymnasium at Flensburg, and subsequently proceeded to Berlin, where he studied mathematics and astronomy under Encke. After taking his Doctor's degree in 1836 he tried to obtain an appointment at the Copenhagen Observatory, in which he was unsuccessful. He then went to Göttingen to pursue his studies under Gauss. He subsequently accompanied Sartorius von Waltershausen to Mount Etna to make a scientific survey of the mountain, and afterwards was made director of the Trigonometrical Survey of Sicily, which position he occupied for some years.

On the revolution breaking out in 1848 he took part against the Government, and was deprived of his appointment. He had to escape on board an English vessel to Malta, whence he soon returned to Sicily, where he took service in the Sicilian army as Captain of Engineers, under Mieroslawski. He soon became major, and under his direction Catania and Messina were fortified. When Palermo fell into the hands of the Neapolitans in May 1849, Peters fled to France, but shortly afterwards proceeded to Constantinople.

Here he made many friends, and the Sultan proposed to send him in charge of a scientific expedition to Syria and Palestine.

Various obstacles stood in the way, and on the Crimean war breaking out in 1854 the expedition was abandoned. This time, however, was valuable to Peters, as it enabled him to become proficient in the Turkish and Arabic languages, which proved of essential service to him of late years in his researches on Ptolemy's Catalogue of Stars.

In 1854 he went to the United States with recommendations from Alexander von Humboldt to the Observatory at Cambridge, Massachusetts. Thence he went to Washington, where he obtained an appointment on the United States Coast Survey. He then became connected with an observatory at Utica, and finally in 1858 was appointed director of the Litchfield Observatory at Clinton, New York, and Professor of Astronomy at Hamilton College, which appointments he held until the day of his death.

Dr. Peters published his first scientific paper in the 13th volume of the *Astronomische Nachrichten*, on the Solar Eclipse of 1836 May 15; and during his life he contributed several papers to the same journal.

About 1845 Peters began his important researches on the Sun, which he continued till some time after 1865. The observations of Sun-spots which he made at Naples in 1845–1846 with a $3\frac{1}{2}$-inch refractor have never been entirely published; but an admirable paper, based upon those observations and entitled "Contributions to the Atmospherology of the Sun," was published by him in 1855 in vol. ix. of the Proceedings of the American Association for the Advancement of Science. In this paper, which has been characterised as much in advance of anything else which has appeared on the subject, he describes the growth and decay of Sun-spots, and records the remarkable phenomena of flashes extending across an umbra with electrical velocity, in these words: "Two of the notches in the margin of a Sun-spot, from opposite sides, step forward into the area, overroofing even a part of the nucleus; and suddenly from their prominent points flashes go out, meeting each other on their way, hanging together for a moment, then breaking off and receding to their points of starting. Soon this electric play begins anew, and continues for a few minutes, ending finally with the connection of the two notches, thus establishing a bridge, and dividing the spot into two parts. The flashes proceed with great speed, but not so that the eye may not follow them distinctly." On the subject of the *proper motion* of Sun-spots, Peters will rank among the earliest observers who clearly recognised this feature. His remarks thereon in the above-mentioned paper may fitly be quoted. He says: "The first fact now, which offers itself, in comparing the heliographic places of one and the same spot for different days, is that the spots are not invariably attached to the Sun's surface, but have *proper motion*. A general proper motion of the spots towards the Equator being recognised, the question is raised naturally: Have they any motion also in longitude? and in what direction—to the east or to the west? The solution of this question is intimately connected with the

determination of the time of rotation. For it is clear, if all the spots had an equal proper motion in longitude, the time of the Sun's rotation, since it is deduced from the spots, would be wrong. In other words, it is the time of rotation of the spots which results, and not that of the Sun itself . . . there can be no doubt of a very considerable motion parallel to the Equator. The displacements in longitude seem even far more considerable than those in latitude. Whether there be a common motion, and in what direction, cannot be decided in the present state of our knowledge of the Sun's rotation."

Carrington thus remarks on the above discovery: "So nearly did this able observer come to the term in latitude without obtaining it, and leave its actual determination to me."

In 1860 he determined to devote the 13-inch refractor of the Litchfield Observatory to the preparation of a series of zodiacal star-charts, to include all stars visible with a power of 80 upon that telescope. His desire was to represent portions of the sky in a picture that in future ages might serve as a sure basis for drawing conclusions as to changes going on in the starry heavens. This was before photography presented itself as a more satisfactory method of realising that aspiration. The first instalment of Peters' zodiacal charts was published in 1882, and at present twenty only are in the hands of astronomers, but many more are nearly or quite completed. The zone observations which form the groundwork of these charts number over 100,000.

The zeal and assiduity with which Peters pursued this work met with their reward in the discovery of the remarkable number of 48 minor planets.

In 1874 Peters acted as chief of the United States expedition to New Zealand to observe the transit of *Venus*. His station was at Queenstown, where he arrived on October 16, and remained exactly three months. His observations were seriously interfered with by bad weather, but he succeeded in securing a good observation of first internal contact.

Some few years ago Peters determined to collate, as far as possible, all existing manuscripts of the catalogue of stars which is be found in the 7th and 8th books of Ptolemy's *Almagest*, so as to produce a more accurate edition of that catalogue than we at present possess. For this purpose he visited the celebrated public libraries at Florence, Venice, Vienna, Paris, Berlin, and other cities on the continent, and collated all the available MSS. of the *Almagest* therein to be found. The collating of the MSS. in this country was undertaken by the writer of this notice, who had independently been working for the same object. In this work Peters showed high intelligence and sagacity in the interpretation of doubtful readings; and the publication of the work may be looked forward to as likely to reveal many interesting points connected with the earliest known catalogue of the positions of stars.

On the morning of July 19, 1890, Dr. Peters was found lying dead upon the doorstep of the college building where he

lodged. His observing cap was on his head, and it is presumed that a sudden spasm from heart disease struck him down while on his way to the observatory to commence his nightly work.

Dr. Peters was a man of the highest integrity and honour, courteous in his bearing and of a most kindly nature. He was an accomplished scholar, and had great linguistic attainments, even to the extent of publishing a scientific paper in the Turkish language. He was an able and accurate mathematician and astronomer, whose fame is due "not to transcendent genius, or brilliant episodes, but to faithful, diligent toil, and life-long devotion to his chosen profession."

He was elected an Associate of this Society January 10, 1879.

Otto August Rosenberger, who at the time of his death was the senior Associate of this Society, was born on August 10, 1800, at Tukkum, in the province of Courland, in Russia. He was the son of a medical man, who, in 1811, migrated to Königsberg, in Prussia, probably in consequence of his brother being the director of the Gymnasium in that city, from whom young Rosenberger then received his early education. He entered the University of Königsberg as a student of mathematics in 1819, and pursued his academical studies till the autumn of 1825.

At this period the immortal Bessel was Director of the Königsberg Observatory. He readily recognised the talent displayed by the foreign student, who was one of his pupils at the University, and in 1823 he appointed him an assistant at the Observatory. In this position he remained for three years. During this period Rosenberger published his first scientific paper, which will be found in the first volume of the *Astronomische Nachrichten*, on the elements of the orbit of the comet of 1821; his second paper, on the elements of the comet of 1818, was published in Bode's *Jahrbuch* for 1824.

In 1826, a vacancy having occurred at the Observatory of Halle, Bessel proposed his assistant for the post, upon which Rosenberger was appointed Extraordinary Professor of Applied Mathematics at the Halle University, and Observer at the Observatory. In quitting Königsberg, Bessel recorded his good services to astronomy by saying: "The journals of the Observatory for the last few years contain proofs of his activity in the functions of this institution, which by his departure has lost an excellent assistant."

Rosenberger entered upon his duties at Halle in October 1826, having in the previous July taken his Doctor's degree at Königsberg. Five years later he was promoted to be Ordinary Professor of the University, and Director of the Observatory. In Halle his activity as an astronomer was seriously hampered by the condition of the Observatory, which had been built in 1790 merely for educational purposes. There were none but antiquated instruments, and not even a reliable clock. Consequently the first task he proposed to himself was to procure a

small meridian circle, a Fraunhofer telescope, of 6 feet focal length, and two clocks. Four years seem to have elapsed before these instruments were obtained and the necessary structural alterations made. But even then no systematic observations appear to have been made, and, indeed, it would seem that observational astronomy was somewhat distasteful to Rosenberger. During the long period of sixty-four years that he held the position of Professor in the University of Halle, he trained numerous pupils in mathematics, but, strange to say, none in astronomy. One of his pupils records from his own personal recollection that Rosenberger could scarcely ever be induced to bring the existing instruments into requisition for the purpose of astronomical instruction. The plea of the instruments being out of date, and the walls of the Observatory damp, hardly affords sufficient explanation of this anomaly in the life of one who to mathematical astronomy was able to contribute work of conspicuous and enduring merit.

In the history of astronomy Rosenberger is known solely by the remarkable investigation of the orbit of Halley's Comet, which he undertook in anticipation of its predicted appearance in 1835. The history of this comet is so well known that it may be considered superfluous to refer in detail to the interest excited in its reappearance in that year. Four mathematicians entered the field to calculate its orbit and determine the time of its perihelion passage—two Frenchmen, Damoiseau and Pontécoulant, and two Germans, Lehmann and Rosenberger. The methods adopted by these four distinguished astronomers in their investigations are well and succinctly explained in the address of Mr. (now Sir George) Airy, in the year 1837, on the occasion of presenting the gold medal of this Society to Professor Rosenberger.* The whole research of Rosenberger on Halley's Comet is contained in a series of papers published in the *Astronomische Nachrichten.*

In the first paper (*Ast. Nach.* No. 180) he gives a calculation of the elements of the orbit at the appearance in 1759, from all available observations made in that year. In No. 196 of the same journal, he investigates the elements at the appearance of 1682, from the observations of Flamsteed, Hevelius, De la Hire, and Picard. These two papers were described by Mr. Airy as "undoubtedly among the most complete papers of the kind that have ever appeared."

In No. 250, Rosenberger investigates the perturbations of the comet from 1682 to 1759. In this paper the effects of all the planets are estimated in the following manner:—"To 30° of eccentric anomaly the perturbations are computed, referring the comet's place to the Sun; from 30° to 60° the perturbations of *Mercury, Venus,* the Earth, and *Mars* are computed, referring the comet's place to the centre of gravity of the solar system;

* *Monthly Notices,* vol. iv. p. 57.

and from 60° to 300° those of *Jupiter*, *Saturn*, and *Uranus* are conducted in the same manner. From 300° to 330°, and then to 360°, the steps of the operation in the first part of the orbit are retraced."

In No. 276, he computes the perturbations from 1759 to 1835, and points out that the perturbations after 300° of eccentric anomaly are so excessively great that a very accurate knowledge of the comet's orbit is necessary to calculate them properly. In a further paper, No. 288, he indicates the importance of frequently changing the elements in the computation of the perturbations. "In some instances, in the first revolution, the elements were altered for every 2° of eccentric anomaly. The effect of these hitherto neglected cautions in computing the perturbations through only 16° of eccentric anomaly is an alteration of four days in the periodic time."

Bessel, in lecturing the following year upon the researches which had been made upon this comet, says: "Rosenberger's calculations have been the most successful ones. Certainly Pontécoulant, by a supplementary calculation published at a subsequent date, though still before the reappearance of the comet, has hit upon the time of perihelion passage more closely than Rosenberger, but a comparison of the other items of the prediction results in Rosenberger's favour. The values ascertained by Rosenberger are so approximately correct that they coincide with the whole series of observations which have now been made, but for some trifling discrepancies, which would have escaped detection had not the observations possessed such high accuracy."

As is well known, the comet was discovered on August 5, 1835, in a position within one degree of the place assigned to it for that day in Rosenberger's Ephemeris, and it arrived at perihelion on November 16, only four days after the time predicted by him.

The high merit of this elaborate investigation is well expressed in the concluding paragraph of Mr. Airy's address already referred to, and which may be here quoted:—"Professor Rosenberger has used the theory of perturbations in its most accurate form, and in one of its most delicate parts he has introduced an important correction. He has computed the perturbations of all the elements for the first as well as the second revolution; Damoiseau and Pontécoulant having only computed the change of mean motion and epoch for the first revolution. He has included in his calculations the effect of several planets which had been totally omitted by other mathematicians. He has not only computed the perturbations, but has also, from the observations of different astronomers at the former appearances, investigated the elements at those times by a process of the most accurate kind. So complete are the whole of these computations, that if names were taken, not from the discoverers of these bodies, or from those who conjecture their identity, but from those who, by

accurate calculations on a uniform system, combine the whole of our information relating to them, we should call this body, not Halley's, but Rosenberger's comet."

It must always be a subject of great regret that with this successful effort Rosenberger should have terminated his labours in astronomy. It does not appear that he published any further scientific work from 1836 to the day of his death.

He gave lectures on mathematics and astronomy regularly, though as a rule but to a small circle of students. Apart from his educational activity, he rendered valuable services to the university and faculty by the readiness with which he undertook manifold administrative functions, as well as by the conscientiousness, precision, and ability with which he performed them. He repeatedly and creditably filled the office of Dean of the Philosophical Faculty. For some period of his life at Halle he took a prominent part in politics, but of late years he seldom appeared in public except to attend some academical function.

On May 13, 1886, he celebrated the rare event of the sixtieth anniversary of his appointment as a professor, on which occasion the Emperor bestowed on him the second class order of the Red Eagle. Professor Rosenberger never married. At the time of his death in 1890, January 23, at the age of nearly ninety years, he was the senior Professor of the University of Halle and of the Philosophical Faculty.

He was elected an Associate of this Society April 10, 1835.

Herman Schultz was born on July 7, 1823, at Nygvarn, in the Swedish province of Södermanland, where his father had a manufactory. His early education was received at home, after which he entered the Lycée of Upsala, and in 1844 he took his degree as Bachelor of the University of that city. He received a Doctor's degree in 1855, and in the following year was nominated 'Professor agrégé' at the University. In 1859 he became Assistant Professor, and was nominated Observer at the Astronomical Observatory. Finally, in 1878 he was appointed ordinary Professor of Astronomy, and Director of the Observatory as successor to Dr. Svanberg.

In the year 1860 the Observatory of Upsala was furnished with an equatorial refractor by Steinheil, the object-glass of which was 24 centimètres diameter, and of 13 feet focal length. The optical part of the instrument was of high excellence, but all the mechanical part of the mounting was very inferior, and necessitated frequent alterations to render the telescope fit for work. With this instrument Schultz made a large number of valuable observations.

After becoming Director, Schultz caused many important alterations and improvements to be made in the buildings of the Observatory. The openings in the transit-room and the room for the prime vertical instrument were much enlarged. Two

small observatories were erected in the garden for the use of students. By means of some funds given to the Observatory by one of his predecessors and by a friend, as well as by a grant from the Swedish Government, Schultz was enabled to enrich the Observatory with several important instruments, including an excellent clock by Hohwü, two chronographs, a small universal instrument by Bamberg, a Zöllner photometer, a transit instrument and a vertical circle, both made by Repsold, and furnished with objectives of 96 millimètres diameter. With the transit instrument he determined the right ascensions of a large number of stars of the 7th magnitude and above.

In 1888, on reaching the age of 65 years, Schultz resigned his position at Upsala and retired to Stockholm. Everything seemed to promise his enjoyment of many years of repose; but during the winter of 1889–90 he was attacked by the epidemic of influenza which then invaded Sweden, and the recovery from this illness left him with an affection of the heart, from which he succumbed on May 8, 1890.

At the opposition of *Mars* in 1862 Schultz took part in observations organised for the determination of a more exact value of the solar parallax. The observations, which were made with a filar micrometer on the Steinheil equatoreal, were published in the *Jahres-Schrift* of the University of Upsala in 1862. The combination of his observations with those made at Santiago gave a value of 8″·87 for the solar parallax.

Schultz made many observations of planets and comets, but the most important work which he has contributed to astronomy is an extensive series of micrometrical measurements of the positions of nebulæ. The first portion of this work, which is written in English, entitled *Micrometrical Observations of* 500 *Nebulæ*, was published in 1874 in the 3rd series of the *Nova Acta* of the Royal Society of Sciences of Upsala; the remaining portion, containing between 200 and 300 observations, is not yet published, but will shortly appear. "The primary object of the work appears to have been the formation of a catalogue of nebulæ whose right ascensions and declinations should be sufficiently exact to serve for a future determination of their proper motions." The observations were commenced in 1863, and, so far as they are published, were continued until 1874. They consist of determinations by means of a wire micrometer of differences of right ascension and declination between 500 nebulæ and neighbouring stars of sufficient brightness to admit of being conveniently observed on the meridian. The whole number of single measures upon which the results depend amounts to about 12,000. Many difficulties were attendant upon making such observations in the latitude of Upsala, particularly the long twilight at the most favourable seasons, and the brilliant auroræ boreales in the winter. Schultz significantly remarks that "the aurora is in many instances as formidable an enemy to such observations as moderate moonlight." Notwithstanding these

difficulties, the discussion of the observations indicates that the probable errors are very small, and, from the care and skill exercised throughout the work, it has justly been considered as one of the most important and valuable of its kind yet accomplished.

In vol. xxxv. of the *Monthly Notices* Schultz published a "Preliminary Catalogue of Nebulæ Observed at Upsala," in which he gave the mean right ascension and declination for 1865·0 of 512 nebulæ. A catalogue of 440 comparison stars used for the observations was published at Stockholm in the *Bihang till Svenska Vetenskaps Akademiens Handlingar* in 1875.

In the same volume of that publication will be found a complete research on the orbit of the minor planet *Alexandra*, entitled "Normalorter och Oskulerande Element för Planeten *Alexandra* (54)." Besides other contributions to astronomy, Schultz published in 1873 a micrometrical determination of the positions of 104 stars in the cluster 20 H viii. *Vulpeculæ*, and in 1875 he contributed to the *Ofversigt* of the Stockholm Academy a paper on Hansen's Theory of Perturbations.

Professor Schultz married in the year 1860 a daughter of the celebrated optician Steinheil, of Munich, who, with their children, two sons and a daughter, survives him.

He was elected an Associate of this Society November 10, 1882.

Proceedings of Observatories.

The following Reports of the proceedings of Observatories during the past year have been received from the Directors of the several Observatories, who are alone responsible for the same.

Royal Observatory, Greenwich.

The regular meridian observations of Sun, Moon, and planets, and of stars from the Working Catalogue prepared in 1887 have been continued as before, the total number of transits observed during the year 1890 being 6203, and of zenith distances 5978. The month of December was not only severely cold, but practically almost useless for observing; but September and October were fine. The total number of stars observed during the year was 2105.

Arrangements were made in the autumn for determining the variation of personal equation with the magnitude of the star. The magnitudes of stars were altered by a constant quantity by placing a wire-gauze screen in front of the object-glass of the transit circle, and part of a transit was observed with clear aperture, part with obscured. The comparison of the two results gives the difference of Personal Equation for a known change of magnitude. The observations are still in progress, having been seriously interrupted in December.

The mean error in R.A. of Hansen's Lunar Tables, with Newcomb's corrections, as deduced from 102 observations with the transit circle in 1890, is $+0^{s}\cdot020$, agreeing well with the results of previous years since 1883.

Six observations of the horizontal flexure of the transit circle in 1890 gave results $+0''\cdot05$, $+0''\cdot28$, $+0''\cdot43$, $+0''\cdot27$, $+0''\cdot47$, and $-0''\cdot35$. The apparent correction to nadir observation deduced from reflection observations of stars is $+0''\cdot076$. No correction for this discordance or for flexure has been applied.

The thermometers placed in the north and south angles of the transit circle shutter opening during the years 1888 and 1889 indicated an unsymmetrical distribution of temperature during observing hours. To eliminate any residual index error, these thermometers were interchanged in January 1890, and the subsequent readings have confirmed the results obtained in 1888–9, detailed in the last report. There seems to be no doubt

of the asymmetry in distribution of temperature, and its investigation is being continued by further experiments.

With the altazimuth the Moon has been observed in the first and last quarters as before.

Comet *a* 1890 (Brooks) has been observed with the Sheepshanks Equatoreal on 22 nights. A new comet-eyepiece with an accurate position circle has been constructed by Messrs. Troughton and Simms for use with this instrument.

Eleven disappearances and eight reappearances of stars occulted by the Moon have been observed, and 37 phenomena of *Jupiter's* Satellites. The meagre results obtained from the very cloudy eclipse of the Sun on June 17 have been already communicated to the Society.

The 28-inch object-glass, for which the Observatory has been waiting so long, is now nearly finished. Sir H. Grubb reports that the second, third, and fourth surfaces are finished, and that the first surface is about three-fourths polished. Much difficulty has been experienced during the past year in turning the south-east dome, which has been much strained in the course of thirty years, and it is proposed to replace it by an iron-framed dome of larger diameter, which will be better suited to the new 28-inch refractor.

The photographic equatoreal intended for charting the heavens was received from Sir H. Grubb on 1890 March 17 and following days, and, after considerable delay, owing to the number of small alterations requisite, is now completely mounted and ready for work. Unfortunately the recent long-continued bad weather has prevented many star photographs being obtained; but a number of experiments have been made on the best method of imprinting the réseau, on the kind of plates to be used, &c., and such star plates as have been obtained are satisfactory. The apparatus used for measuring the Transit of *Venus* photographs has been modified for experimental use with the chart plates, and with it the errors of the two réseaux received from Prof. Vogel on May 6 are being determined, this work being about half completed for one réseau. It is hoped that the experience gained by using this apparatus will suggest the best form of micrometer to be ultimately adopted.

Mr. Hollis has been occupied with the selection of guiding stars for the plates of the astrophotographic chart. These stars have been selected from the Bonn *Durchmusterung* from Decl. +60° to the north pole. For the zones +60° to +65° the stars have been identified in the recently published Helsingfors Catalogue, and reduced to epoch 1900, and micrometer settings for the guiding telescope computed, the whole being arranged in complete catalogue form. For zones +81° to +84° (both inclusive) the stars have been identified in Carrington's and other catalogues, precessions and secular variations computed for the Carrington stars, and the reduction of places to epoch 1900 is now proceeding.

Observations of the displacements of lines in stellar spectra have been continued, as in former years, for the determination of the motions of stars in the line of sight; 504 measures have been made of the displacement of the F line in the spectra of 44 stars, and 34 measures of that of the *b* lines in the spectra of 9 stars, besides 84 measures of lines in the spectra of Sun, Moon, or planets, as a check on the adjustment of the instrument, and on the general accuracy of the work. Seven measures were also obtained on one night of the position of the chief line in the spectrum of the great nebula of Orion as compared with the less refrangible line of the bright pair of air-lines which are nearly coincident with the nebular line in question.

Photographs of the Sun have been taken with the photo-heliograph on 223 days, and of these 495 have been selected for preservation, including 10 photographs of the partial eclipse of June 17, and 18 photographs, with a double image of the Sun, taken to determine the position of the wires with reference to the parallel of declination. Photographs have been received from India and Mauritius up to 1890 November 19, and there are thus only four days left in the year ending on that date for which no photograph is yet available for measurement.

The revival in the solar activity, first remarked in June 1889, has become more evident in 1890, both in the number of spots observed and in the latitudes in which they are placed. Several fine groups have appeared in the latter half of the year, the group first seen on July 28 and reappearing in the two following rotations being especially noteworthy.

The observations for the longitude of Paris made in 1888 have now been completely reduced, and the definitive results found by the French and English observers are respectively $9^m\ 21^s{\cdot}04$ and $9^m\ 20^s{\cdot}84$. In view of this unsatisfactory discordance (for some account of which see *Monthly Notices*, vol. li. page 155), it seems desirable that the determination should be repeated with interchange of instruments as well as of observers.

Three naval officers have during the past year been instructed in transit observations. Mr. S. Hirayama, of the Tokio Observatory, is at present studying the work and general organisation of the Observatory.

The volume of Greenwich Observations for 1888 was passed for press in May last, and has been distributed. The volume for 1889 is well advanced.

Royal Observatory, Edinburgh.

The committee nominated by H.M. Secretary for Scotland for the consideration of the site and plans for the new observatory now consists of Lord Crawford, Professor Tait, Lord McLaren, Mr. R. McLeod, Queen's and Lord Treasurer's Remembrancer,

and Professor Copeland. During the past year repeated meetings were held, but, contrary to expectation, the new buildings have not yet been commenced. The ground so liberally ceded by the city of Edinburgh has, indeed, been transferred to the Crown, and complete plans of the proposed buildings, prepared by H.M. Office of Works, were laid before the committee as early as June 2. In a slightly modified form these plans were finally submitted by the committee to the Marquis of Lothian. It is greatly to be hoped that they will receive the sanction of the Treasury before the close of the present financial year, as, until the new buildings are erected, no important work can be taken in hand with the beautiful astronomical instruments now at Dunecht.

In March Dr. Becker went to Dunecht to take exact measures of the foundations of the chief instruments, the dome of the equatoreal, &c., in readiness for their removal. On the only two fine moonless nights that occurred during his stay a number of nebulæ were observed with the transit-circle. In the autumn these and former determinations were reduced to the beginning of the year of observation.

The spectroscopic observations of solar light at medium and low altitudes taken on the Barmekin of Echt in the years 1887–89 were completely reduced by Dr. Becker in the spring, and the resulting spectra expressed in ten large drawings, which were reproduced on a smaller scale by photo-lithography. A comprehensive paper on the subject was communicated to the Royal Society of Edinburgh in July, and has since been published in their Transactions. Reprints of this paper have been distributed to institutions and individuals specially interested in the subject. The part of the spectrum thus dealt with extends from W. L. 6024 to W. L. 4861. It is proposed to extend these investigations to the whole spectrum, if possible, at two stations, at one of which the air is highly charged with moisture, the driest accessible climate being selected for the other.

In October and November much time was devoted to erecting, revising, and adjusting the 12-inch Browning-With reflector in a part of the space acquired for the new observatory where it is not likely to be in the way. The reversing transit instrument used in the previous year in testing the site was moved exactly into the meridian of the proposed new transit-house, where it is adjusted to serve as a temporary collimator while the transit-circle is being placed in position. Some arrangement of this kind is the more desirable because there are no screw adjustments to the Y's of the Dunecht transit-circle. When dropped into the prime vertical Y's the reversing transit instrument will serve to orientate the chief façade of the main observatory building. The perfectly exposed position of these huts on a bare hill, together with their distance from the old observatory and the assistants' quarters, forcibly impress the necessity for forthwith commencing the new structures.

Within the year nine numbers of the "Edinburgh Circulars" were sent out, all referring to comets. The printed catalogue of the Dunecht section of the library is now in course of distribution.

The meteorological readings, reductions, and preparation of weather returns for the Registrar-General for Scotland, as well as the distribution of time-signals, have been continued as in former years, under the care of Mr. T. Heath.

Royal Observatory, Cape of Good Hope.

Observations with the transit-circle have been continued regularly throughout the year.

The chief objects of observation have been the Sun, *Mercury* and *Venus*, stars in the list of the Cape Ten-year Catalogue for 1890, stars occulted by the Moon, stars employed in the latitude determinations of the Geodetic Survey of South Africa, comet comparison stars, and stars employed in zones for determining the scale value of the heliometer.

The work accomplished with the transit-circle in 1890 has been as follows:—

		R.A.	N.P.D.
No. of observations of ⊙.	Both limbs	67	76
,, ,,	⊙. One limb only	5	1
,, ,,	Mercury	30	28
,, ,,	Venus	45	48
,, ,,	Azimuth Stars	410	
,, ,,	Stars by Reflection	8	38
,, ,,	Observations with screens for personal error depending on magnitude	2524	
,, ,,	Catalogue Stars	3628	3858
	Total	6717	4512

The weather has been exceptionally cloudy during the year, and the definition often so bad during the day as to make it undesirable to make observations; hence the comparatively small number of observed transits of the Sun.

It will be seen that the meridian observations include an extensive series of observations for personal error depending on magnitude.

With the zenith telescope 638 pairs of stars have been observed by Talcott's (Horrebow's) method, partly in connection with Kapteyn's method of latitude determination, partly for control of the law of flexure of the transit-circle, and for correction of the northern and southern systems of declination.

This work completes a series of observations which was begun in 1887 on 414 pairs of stars uniformly distributed over the heavens, and so selected that in each pair the times of upper (or lower) culmination of the two stars differ only a few minutes of time, and the difference of their opposite zenith distance does not exceed 10′ of arc. The range of zenith distance is from 2° to 80°. Each pair has been observed at least on six nights. All these stars are included in the list of the Cape Ten-year Catalogue for 1890, and will therefore be connected with all stars to the fifth magnitude south of the Equator, and with all stars in Auwers' *Fundamental Zone* lists, and all stars in the British and American *Nautical Almanacs*, the *Connaissance des Temps*, and the *Berlin Jahrbuch*, which culminate within 80° Z. D. of the Cape.

The following occultations of stars by the Moon have been observed :—

Disappearances at the dark limb...	9
Reappearances at the dark limb	13

No observations of comets have been made throughout the year.

A strenuous effort was made to complete the determination of the absolute division errors of the heliometer scales. As mentioned in last report, this work was suspended in February 1889, because Dr. Gill found that, when observing every night and every morning, he could not expose his eyes to the additional strain of making observations for division errors by day. The work was resumed after the *Victoria* and *Sappho* observations in November 1889, and was continued without intermission till its conclusion in the end of February 1890.

Tables have been constructed giving the equivalents of all possible combinations of scale readings in arc, corrected for division error, together with auxiliary tables giving equivalents of the screw readings in arc, with corrections (in arc) for run. These tables render the rigid reduction of the observations exceedingly simple and convenient.

In February and March some additional observations of the distortion zones (mentioned in last year's report) were made, in order to determine whether the radius of motion of the optical centres of the segments is coincident with the focal length of the object-glass. (In other words, to determine whether, in converting observed distances into arc, it is necessary to introduce a term depending on the square of the distance.) A discussion of the observations showed that, within the limits of the probable error of its determination, the term depending on the square of the distance is insensible, but that a much larger number of observations is required to settle the question with an accuracy corresponding to the precision of the determinations of division error. The chief work to which the heliometer has been devoted

during the year has been the triangulation of the *Victoria* comparison stars. The reasons which led to this undertaking are explained in the conclusion of the Report of last year. A programme for the observations was prepared by H.M. Astronomer.

Having regard to the necessary conditions, a programme of observation was prepared requiring 323 observations in all (each of four pointings), which provides for observations of the distance of each pair, from one to five times, with observations of the standard pair of stars before and after each four of the other pairs observed in the course of a night's work. The work was begun on April 12 (i.e. so soon as the stars could be observed for two hours at a sufficient altitude before sunrise), and was continued till November 14, when the stars were too near the Sun for observation at a favourable altitude in the evening twilight. The programme was completely observed twice at the Cape, and all the pairs set down for a single observation were observed three times instead of twice. At Yale the programme was completely observed once, and most of the stars set down for a single observation were observed twice. At Göttingen a series similar to that at Yale has been secured. Thus, in general, each pair has been observed at least five times, and in some cases as many as twenty times, in all, and, as most of the principal stars are connected in the triangulation with from eight to fifteen other stars, there can be no doubt that their ultimate relative places will be fixed with all necessary accuracy.

In December a number of observations were made of β *Orionis*, both east and west of the meridian, to determine whether any error depending on the hour-angle could enter into the investigation of the parallax of that star.

The actual number of observations made with the heliometer during the year is as follows:—

	Pointings.
Observations of Zones	132
Victoria Triangulation Standards	1320
Other pairs	3756
Observations of β *Orionis*	384
Total...	5592

The mounting of the new photographic equatoreal by Sir Howard Grubb reached the Cape on June 12, and was erected without difficulty by June 21. The object-glasses, réseaux, and dark slides arrived on August 9, and observations for focus were begun the same night. The general mechanical features of the instrument are excellent, but experience has shown some modifications which should be introduced to facilitate speed and accuracy of working. The clock-work and slow motions leave nothing to be desired. There is a slight optical imperfection, which Sir Howard Grubb has undertaken to remove, and the object-

glass will be brought to England for this purpose by H. M. Astronomer.

A number of experiments have been made for determining the best method of obtaining sharp impressions of réseaux.

For the double purpose of practically testing the accuracy of photographic methods and of strengthening the determination of the relative positions of the comparison stars observed with *Iris*, *Victoria*, and *Sappho*, a complete photographic triangulation of these stars has been made with carefully distributed overlapping plates. Each plate, besides a photograph of a particular field, contains a picture of the Standard Stars taken nearly at the same hour-angle as that of the field intended for measurement.

These Standard Stars (nearly 2° apart) therefore provide means for determining the orientation as well as the scale value of the plate. A comparison of the results of the photographic triangulation with the results of the heliometric triangulation of the *Victoria* stars will afford complete data for determining the optical distortion of the photographic field. When this has been done, the reduction of the photographic triangulation of the *Iris* and *Sappho* stars becomes a comparatively easy matter.

The number of photographs secured has been—

In the *Victoria* Triangulation	218	exposures
„ *Sappho* „	282	„
„ *Iris* „	86	„
For various experimental purposes	32	„

In the beginning of the year the U.S.S. "Pensacola," with the American eclipse party, under Professor Todd, visited the Cape. Mr. Preston, of the United States Coast Survey, and Cadet Patton, of the United States Navy, made a complete series of pendulum and magnetic observations. Professor Cleveland Abbe carried out various meteorological investigations at the observatory. Every facility was given to the observatory staff by Professor Todd, and by every member of his party, to examine and in some cases to test their fine collection of astronomical and other instruments. Their visit will be long and pleasantly remembered by every member of the observatory staff.

Mr. Harold Jacoby, assistant at the Columbia College Observatory, and a member of the eclipse party, remained at the Cape to study the practical working of the heliometer. Mr. Jacoby's services were of great value, not only as an observer, but as an excellent computer. He remained at the Cape till August 6.

During the recent tour of His Excellency Sir Henry Loch (H.M. High Commissioner for South Africa) in Bechuanaland and British Zambesia, arrangements were made for exchanging telegraphic signals for longitude with Lieut. Duncan (late R.N.), who accompanied the party. Mr. Duncan's time observations

were made with a sextant and artificial horizon. The results have been reduced, and important corrections of the previously adopted latitudes and longitudes obtained.

Mr. Newdigate, Colonial Government Surveyor, visited the observatory during the month of November for a course of training in astronomical surveying. He is now engaged in important longitude work in British Zambesia, and exchanges signals with the observatory from time to time in the course of his work.

The field work of the Geodetic Survey makes rapid progress. Major Morris, R.E., has completed the measurement of a longitude chain of triangles connecting the southern triangles of Maclear's work with the new system of Geodetic triangles at Port Elizabeth, and is now making steady progress in measurement of a meridian chain of triangles from Port Elizabeth northwards to Kimberley.

A reconnaissance survey for a longitude chain of triangles connecting Maclear's meridian arc with the Port Elizabeth–Kimberley arc, along the parallel of 31° S. latitude, is nearly completed. This arc joins the Kimberley meridian arc near the town of Hanover, and is therefore called the Hanover longitude arc.

The Kimberley meridian arc will be completed by the measurement of a base line at Kimberley in the course of the current year. The accurate measurement of the Hanover arc will immediately follow, and will complete the system of Geodetic triangles in the Cape Colony.

The extension of the Natal meridian chain through the Transvaal has been delayed by the pressing demand for surveys of boundaries and mining areas, but it is hoped that the work will now soon be begun.

The MSS. observations of the late Commander Pullen have been forwarded to H.M. Astronomer by the Hydrographer, and have been completely reduced and prepared for press. The results include accurate determinations of the latitude and longitude of Port Nolloth, Mossamedes, Benguela, St. Paul de Loanda, and St. Thomé, each on at least three nights' work and one night's determination of the longitude of Bonny. Commander Pullen's observations prove to be of the highest excellence. His probable error for a time determination at stations near the Equator from observed altitudes of two stars, one E. and the other W. of the Meridian, amounts to less than $\pm 0^s{\cdot}03$.

Partial effect has been given by the Lords Commissioners of the Admiralty to the recommendations of H.M. Astronomer with reference to a supply of computers.

A vigorous effort has been made to overtake the arrears of reduction mentioned in last year's Report.

The results of the Cape Meridian Observations of the Sun, *Mercury* and *Venus* to the end of 1889 have been communicated to Professor Newcomb for incorporation in the discussion of the

constants of his new Planetary Tables, and considerable progress has been made in the reduction of the long series of heliometer observations.

But more computing aid is essential for the reduction of the long and important series of observations which have been accumulated at the Cape.

A sum of 100*l.* has been offered by Miss Bruce, through Professor Pickering, and has been gratefully accepted, in aid of the reduction of the observations for Solar Parallax, and of construction of the maps of the Photographic Durchmusterung.

The Meteorological Observations made in the year 1889 at the observatory, together with those taken in different parts of the Colony, have been printed in the Report of the Cape Meteorological Commission.

Professor J. C. Kapteyn has measured definitively 389 negatives of the plates of the Southern Photographic Durchmusterung, covering 8769 square degrees of the sky. This work represents 489,490 observations of about 193,000 stars, or about 63% of the whole work.

The reductions of the positions are completed for all the zones 19°–34° and 57½°–90°.

The reductions of the magnitudes for the same zones have been completed once, and an independent duplicate reduction is nearly completed.

The positions of Stone's Catalogue have been reduced to 1875·0 and are entered in the observation books for the zone 19°–34°. The same has been done for Gould's General Catalogue, the Cordoba Zones, Oeltzen's Argelander, and Lalande, for the zones 19°–34° and 57½°–90°.

Armagh Observatory.

The refractor has been used for observations of nebulæ and physical observations of *Jupiter*, but during the greater part of the year the weather was singularly unfavourable for observing.

Cambridge Observatory.

The work done with the transit-circle comprises :—

Four hundred and eighty-three observations for clock correction; 57 direct and 22 reflected observations of *Polaris* above the pole, and 63 direct and 20 reflected observations of *Polaris* below the pole; 630 observations of zone stars; 18 observations of *Mars* near opposition, and 39 observations of the stars selected to be observed with *Mars*; and 4 observations of stars which had been compared with Brooks' Comet, making a total of 1,336 observations.

The nadir point was observed 158 times; and level and collimation each 149 times.

Observations of the solar eclipse of June 17 were completely frustrated by rain and dense clouds: we simply caught a glimpse of it near the end; but lost sight of it again about a minute before the last contact.

In the early part of the year a fresh determination of the intervals of the wires was made from 112 observations of *Polaris* taken in 1889.

The apparent right ascensions and north polar distances are calculated up to the end of this year; the R.A.s and N.P.D.s, referred to the mean equinox at the beginning of the year, are calculated up to the end of 1889. The reduction to epoch is completed for 0^h R.A. to the end of 1889; for the other zone stars, in R.A. to the end of 1885, in N.P.D. to the end of June 1887.

Considerable progress has been made in arranging the zone stars in order of right ascension for the catalogue.

The copy for press of the next volume of *Observations* is far advanced, and the earlier sheets are in the hands of the printers; and it is intended to commence almost immediately the preparation of the catalogue for the press.

Thirty-nine observations of *Polaris* made in 1890 up to Oct. 12 and one observation in 1889, each taken direct and reflected, 20 being above and 20 below pole, give for the latitude $52° 12' 51''·60$, precisely the same as that obtained by Professor Challis with the mural circle. The same observations give for the flexure at the pole $+0''·328$. The coefficient of flexure, obtained by the aid of the collimators, and used since the last determination, is $-0''·50$. Supposing, as we have done, that the flexure varies as the sine of the zenith distance, + when south, the flexure at the pole would be $-0''·50 \sin(-37° 47') = +0''·306$, differing only $0''·02$ from the above.

Numerous applications for places of stars contained in our zone have been promptly attended to. The individual results have been found satisfactory.

The places of *Victoria* and *Sappho* and the comparison stars, obtained from the observations in 1889, have been communicated to the Royal Astronomical Society, and are printed in the *Monthly Notices*.

The preparation of the building for the 25-inch refractor, the munificent gift of the late Mr. Newall, of Gateshead, has already commenced, with the valuable co-operation of his son, Mr. H. F. Newall, M.A., of this University. The object-glass has arrived safely at this Observatory.

Dunsink Observatory.

At the date of last report the observations of *Sappho* and the comparison stars chosen by Dr. Gill were in progress, and we hoped in the event of fine weather to be able to make these observations complete. In this, however, we were disappointed, as the weather remained obstinately unfavourable all the month of January, until the stars arrived on the meridian too early to admit of useful work on them.

The reduction of the observations had been postponed till the series was complete, as there was some uncertainty with regard to the intervals of the spider lines in the meridian circle, and it was intended to redetermine them from the transits of the stars themselves. The work of reduction was accordingly taken in hand in February, the meridian circle at the same time being used for observing the stars of the proper motion working list referred to in former reports.

This work was interrupted shortly after its commencement by the erection of the greater part of the reflecting photo-telescope presented to the Observatory by Mr. Isaac Roberts. Although the mirror had not been resilvered, nor the photographic parts finished, we pushed on the erection of the rest of the apparatus, intending, by observations with the 5-inch achromatic, which is attached as a "pilot" telescope, to get the instrument into adjustment, and to test the running of the clock and the performance of the slow motion in R.A., which, having been originally designed by Cooke, the maker, for merely optical work, there was reason to fear might prove inadequate for the more delicate requirements of photography. It was soon found, however, that it would be necessary to test the clock more thoroughly by taking photographs with it. The mirror and plate-holder were accordingly inserted in their places in the month of June, and systematic photographic work commenced.

It was, of course, first necessary to go through a good deal of preliminary work with the instrument in order to acquire the requisite skill in this delicate species of observation to qualify one to pronounce on the performance of the clock. It became apparent, however, as these experiments went on that the clock was affected with a periodic error, of great regularity, occurring in a period of 33 secs., and, although careful and repeated attempts were made to trace the error to its source, it was found impossible to localise it.

The slow motion in R.A., too, which was effected by a cord acting on a pair of differential wheels, was found not to be sufficiently smooth to give good results. Accordingly, it was decided to remodel the clock completely, and, instead of conveying the clock-motion through a large number of wheels, to take it almost direct from the spindle, and to put in one of Grubb's latest forms of slow motion in R.A.

This alteration, it is hoped, will effectually eliminate the error, and enable us to proceed with the parallax work, which it is intended to prosecute by the aid of photography.

For the purpose of measuring the plates a micrometer-microscope, similar to the Oxford instrument, has been completed for us during the year by Messrs. Troughton and Simms.

Since the telescope has been dismantled for the alteration mentioned above, and for other requisite changes in some of the minor parts, such as a new eye-end to the "pilot," &c., the reductions of the *Sappho* stars have been completed, and the results sent for publication to the Royal Astronomical Society. They have already appeared in the *Monthly Notices* for January.

Glasgow Observatory.

The operations at the Glasgow Observatory during the past year have been devoted exclusively to a series of observations of stars with the transit-circle, the desirability of which had been suggested by a comparison of the places of the telescopic stars in the Glasgow catalogue with the corresponding star places in Weisse's first catalogue of Bessel. The work is now drawing to a close, and it is expected that in a few months hence the results will be in the hands of astronomers.

Kew Observatory, Richmond.

The ordinary routine of meteorological and magnetical observations has been carried out during the year, and, as usual, large numbers of various scientific instruments have undergone examination.

Sketches of Sun-spots have been made on 198 days, and the groups numbered after Schwabe's method.

Solar and sidereal transits have been occasionally observed as a check on the signalled times.

During the past summer 225 series of observations of the Sun's actinic power have been made with Violle's actinometer, described in the last Annual Report, upon the plan arranged by General Strachey and Mr. Blanford.

By the kindness of Mr. C. Baker, of High Holborn, the Observatory has received the original sunshine-record cards obtained by the late Mr. Rand Capron, F.R.A.S., at his observatory near Guildford, Surrey, during the years 1880 to 1887.

The Winstanley radiograph, deposited at the Observatory in 1880, was recently repaired at the suggestion of Mr. R. H. Scott, and set up on the lawn. Its action is, however, not

considered satisfactory, and it has been decided to return it to the owner.

The swinging of the invariable pendulums at the Royal Observatory, Greenwich, having been completed during the past winter, the apparatus was dismounted and returned to Kew, where it is now stored awaiting further disposal. A paper describing the operations, and giving full details of the values of the vibration numbers obtained at Kew and at Greenwich, has been contributed to the Royal Society by General Walker (see *Phil. Trans.* vol. 181, A, p. 537). The result shows the number of vibrations made by a seconds pendulum in one day to be 0·64 greater at Kew than at Greenwich.

At the suggestion of General Strachey, Chairman of the Meteorological Council, a new departure has been made in the photography of clouds during the past year, with the view of simplifying the operations of determining their height and the velocity of their movements. Two cameras have been rigidly fixed on their stands, with the axes of their lenses pointed directly to the zenith, and photographs are now taken simultaneously of the area of the sky surrounding the zenith within a circle of a radius of about 15°. These photographs are superposed one on the other, so that the two pictures shall appear to coincide, and a simple measurement of the distance between the images of the zenith points, which are marked by intersecting lines on the photographs, gives a means of readily determining the height of the cloud above the surface of the ground. A second measurement made in like manner of the displacement of the zeniths in a second pair of photographs taken after a given interval of time serves to show the rate of travel of the cloud and the direction in which it is moving at the instant of observation. Twenty groups of clouds, giving heights extending from 1½ mile to 8 miles, and having rates of horizontal motion from 5 miles to 64 miles per hour, have been photographed and measured in this manner during the past summer.

The necessary apparatus to enable the examination of photographic lenses for cameras to be prosecuted at the Observatory, with the view of granting certificates to the owners or purchasers of such articles, has been prepared, and it is in contemplation to adopt a system of examination of lenses which shall provide, first, for a comparatively rough or cursory trial which will enable a person to form a general idea of the capabilities of a lens; and, secondly, a more lengthy and careful trial, for which a higher fee will be charged, and which will give full particulars as to the various qualities an acquaintance with which is necessary to possess a full knowledge of the instrument. Captain Abney and other gentlemen have rendered the Committee much assistance in the practical arrangement of the details of this lens testing.

Liverpool Observatory, Bidston, Birkenhead.

The general work has been for the most part of a similar character to that during previous years. It has consisted chiefly of observations of stars with the transit instrument for the determination of clock errors; the communication of Greenwich mean time to the port by the firing at 1^h P.M. daily, Sundays excepted, of the time-gun on the pier-head of the Morpeth Dock, Birkenhead; the testing in definite and equidistant temperatures, in order to determine their thermal errors, of all chronometers sent to the Observatory. The officers of the Pacific Steam Navigation Company continue to be supplied with tables of the probable rates of their chronometers for the ensuing voyage in each five degrees Fahrenheit from 45° to 95° inclusive.

The meteorological work has been carried on as heretofore. No break has occurred in the records of the self-registering instruments. From the increasing number of applications for extracts from these records they appear to be found of much practical utility, as affording reliable evidence of the state of the weather at definite times.

Radcliffe Observatory, Oxford.

During the year 1890 the attention of the observers has been chiefly directed to the completion of the observations required for a General Catalogue of Stars between 90° and 115° N.P.D.

In order, however, to fill up gaps, the places of the stars have been charted, and stars to a much lower magnitude than 7–8 have been inserted, when necessary, in the Working Catalogue. Special double watches have been kept up during the year to hasten the conclusion of the work.

The Sun and Moon have been observed on the meridian at each favourable opportunity. The lunar results are in preparation, and will shortly be forwarded to the Society for publication.

The total number of observations during 1890 amounted to R.A. 3037, N.P.D. 2543.

A discussion of the solar observations made with the transit-circle during the years 1884–1886 shows that the following corrections appear to be required:—

	1884.	1885.	1886.
	s	s	s
Mean correction to adopted R.A. of clock stars	+0·049	+0·039	+0·037
	″	″	″
Mean correction to N.P.D. observations ...	−0·256	−0·157	−0·190
Correction to adopted tabular obliquity ...	+0·260	+0·166	+0·450

Preparations were made to observe the contacts of the solar eclipse of June 17, but only one observation through thick cloud was secured.

The reductions of the observations made in 1890 are in an advanced state; the star ledger for 1889 is in progress; and the printed volume of results for 1886 has been distributed.

The meteorological work has been continued as usual, and some further experiments on the moisture of the air have been made.

Oxford University Observatory.

Since the communication of the last report of the Oxford University Observatory, the large equatoreal has been thoroughly completed for the purposes of the International Star Chart. The photo-telescope may be regarded as eminently satisfactory and fully adequate for the refined purposes for which it is intended. The camera at the eye-end has been greatly modified in accordance with certain improvements suggested by the Astronomer Royal. A micrometer also, of somewhat elaborate construction, has been added to the refractor for the purpose of allineating it in any required manner with the photo-telescope. Some difficulty has naturally attended this arrangement, inasmuch as it is necessary to place a photographic plate in such a position as to give the images of the stars, referred to the mean equinox of 1900·0. A considerable number of trial plates of the *Pleiades*, as well as of the stars in the zone assigned to the Oxford University Observatory, have been taken to test the accuracy of the adjustments and the efficiency of the equipments provided, and it is believed that the preliminary difficulties attending the project have been overcome.

In order to obtain the magnitudes of the fainter stars up to magnitude fourteen, by direct measurement, rather than by mere estimation, there has been procured from Mr. Hilger a more delicate wedge of neutral glass than has heretofore been constructed. The object of this arrangement is to afford a means of comparison between the photographic and visual magnitudes of very faint stars. Having in view the vast number of these faintly illuminated objects, there has also been devised a simple arrangement for measuring the diameter of star discs with extreme rapidity and sufficient accuracy. The instrument in question is, in fact, nothing more than two lines, engraved on glass, meeting each other at a very small angle. One of these lines is graduated to millimètres, and by means of these divisions the diameters are read off at once. This method has been found practically efficient for the purpose.

Mr. Simms has been consulted in respect of a new instrument for the measurement of the plates taken in the zone of stars referred to. The instrument suggested is of extreme simplicity, with every promise of affording the requisite accuracy, combined with great economy both of labour and time. This economy is also very materially influenced by the admirable

character of the réseaux supplied by Professor Vogel, of the Potsdam Observatory. Experiments have been made which furnish a hope that the photographic plates can be reproduced on paper with great readiness and effect, and it is expected with adequate permanence.

All the above arrangements have unavoidably occupied, to a great extent, the time and attention of the Observatory; nevertheless, the progress of the parallax work with reference to the stars of the second magnitude has proceeded with regularity. The determinations of the parallax of nineteen stars are fully completed, and the necessary observations of the remaining stars of the second magnitude whose parallax is sought (ten in number) have been obtained. Of these ten stars four are fully measured and await computation. Observations are in systematic progress for the determination of parallaxes of γ *Draconis*, as well as of the two faint stars of comparison which give a sensible difference in the relative parallax of α *Cephei*. These stars are being observed with the 13-inch photo-telescope for the purpose of observing fainter stars at a greater angular distance from the centre than could easily be obtained on the small plates taken with the De la Rue mirror.

Some experiments were made towards ascertaining the parallax of several of the better-known planetary nebulæ. It was, however, found that the necessary exposures were so protracted that there would be too great an uncertainty in the corrections for refraction to afford a hope of ultimate success. This valuable and interesting investigation I am thus reluctantly compelled to relegate to other observatories possessing larger optical appliances.

In offering this report of the year's work it must not be overlooked that, in combination with original research, a main duty of the director is also to afford instruction to University students. This necessarily consumes a considerable amount of time and attention, and nothing but the efficiency of the two assistants could have enabled him to produce the results specified above.

Temple Observatory, Rugby.

The usual instruction to members of the school has proceeded as heretofore, and although there is not time to teach much, still it is hoped that some will leave school with a taste for some branch of astronomy. Mr. Seabroke has continued his measurements of the motions of stars in the line of sight with a spectroscope having three prisms, one of 60° and two others of 45°, with a collimator of $1\frac{1}{2}$-inch aperture on the 12-inch reflector. Mr. Highton has measured a considerable number of double stars, but owing to his illness nothing has been done in this line during the latter part of the year.

The measures of double stars made during the past four years have been collected and recently published in the *Memoirs* of the Society.

Stonyhurst College Observatory.

In the astronomical department of this Observatory the usual observations of the solar spots and faculæ have been continued without omission of any opportunity for noting their positions and sketching their forms. The collection of drawings made during the last ten years has been under discussion during the year, and it is hoped that the results may soon be presented to the Society. The chromosphere and prominences have not been neglected; but these have suffered more than the spots from unfavourable weather and other untoward circumstances.

The solar spectrometer, constructed by Hilger and furnished with a Rowland grating of 14,438 lines to the inch, has been transferred to a more convenient position for use. A heliostat of very simple and inexpensive make has been mounted on the roof of the spectrometer-room, so as to be completely under the control of the observer. It consists of a short polar axis carrying a plain silver-on-glass mirror at its lower extremity. The mirror has a free motion in declination, and is controlled by a fine flexible wire working against a spiral spring, at the opposite extremities of its declination-diameter. The wire passes through the upper pivot of the polar axis and over a pulley into the observing-room, where it is coiled over a reducing gear for small movements. The second or fixed mirror has been carefully placed with its centre at the point of intersection of the line of collimation of the slit-lens and the produced line of the polar axis. And there is ample room between the fixed mirror and the slit for an objective of 9 feet focal length. A 6-inch objective of 7 feet focal length, by Alvan Clark, has been in use since the beginning of the summer, and the two mirrors have stood the test very well, the solar image on the slit being well defined, with sharp limb and no appearance of multiple images from the glass surface reflections. The mirrors were supplied by Hilger, having been specially ground for the purpose.

The heliostat is driven by a small pendulum clock fixed to the wall inside the observing-room, the connection being made by a light steel endless chain guided by a pair of friction wheels.

The photograms obtained during the summer months give reasonable hope of useful work to be done in the photographic mapping of the spectrum, with the object of watching for any alteration in the metallic lines.

A reflector of the Cassegrainian form is now mounted in place of the Clark refractor, but no experiments have yet been made

with it. It gives a much larger image of the Sun, which may prove more serviceable for the spectra of the spots. And the loss of light is not likely to be any serious drawback, judging from some surprisingly good results obtained without any form of condenser for the solar rays.

A number of experimental photograms of stellar spectra have also been obtained during the year. But progress in this direction has been very slow. The necessity for long exposures, and the unfavourable weather have kept experiments waiting, so that much remains yet to be done before deciding upon the instrument to be used and the class of work that can be usefully adopted.

Mr. Common's Observatory, Ealing.

The weather during the past year has been very unfavourable for observation at Ealing. Advantage has been taken of every available night, but the 5-foot telescope has only been in use 48 nights since March 1890, and only 24 of these were suitable for nebula photography. In all 31 photographs of nebulæ and clusters have been obtained. The principal nebula photographs are *Orion* 6 (one with 2 hours 35 minutes' exposure, and one with 2 hours' exposure on plates stained with erythrosin; the first mentioned is much the best hitherto obtained); the *Dumb-bell* nebula 5 (the best with 110 minutes' exposure on July 24, showing a large amount of detail); M 77, 3 (one with 150 minutes' exposure, showing the spiral structure very clearly); M 99, 2 (with exposures of 2 hours and 2¼ hours, with spiral structure clearly shown); M 96, 1 hour; M 88, 1 hour; M 59 and 60, 2 hours 5 minutes; Gen. Cat. 4045, 2 hours; Gen. Cat. 2203, 2207, 2211, 1 hour; and the *Pleiades*, 1 hour, showing nebulæ. Amongst the clusters photographed may be mentioned those of M 2 (four photographs) and of M 5 (four photographs), the latter showing some new variable stars near the cluster; see *Monthly Notices*, vol. l., page 519, June 1890. Photographs of the Moon have been obtained on nine nights during the year, and *Uranus* and its satellites have been photographed on two occasions.

Observations have been made of the satellites and general appearances of *Saturn*, *Uranus*, and *Neptune* whenever possible, the observations of Mimas being communicated to the Society in May 1890, and published in the *Monthly Notices*, vol. l., page 404.

A double-wire micrometer, with position-circle and electric-light illumination, has been made for the 5-foot telescope, and also a star spectroscope (which was supplied at the end of 1890) fitted with special apparatus for watching the slit during the long exposures necessary for photographing the spectra of nebulæ. Up to the present time, owing to bad weather, only preliminary

work on the *Orion* nebula has been possible with the spectroscope. The spectrum of this nebula has been observed on three occasions (the only three possible since November), but no new lines have been detected.

As mentioned in the last report, the figure of the 5-foot mirror is not perfectly satisfactory owing to a slight ellipticity of the star images seen under high magnification, this ellipticity being probably due to the fact that the disc of glass rested in a sloping position for some years. The new 5-foot disc has been obtained from France, and the grinding of this will be proceeded with at once. Both the grinding machines have been kept in constant work. A 36-inch mirror of 11 feet 3 inches focal length has been made for the Science and Art Department, South Kensington, and two 30-inch mirrors of the same focal length have also been finished, one of these being made with a spherical instead of a parabolic curve to be used in the testing of flat mirror surfaces. Another 30-inch parabolic mirror is now in hand and nearly finished. Two 20-inch mirrors of 45 inches focal length have also been finished during the year, and have been thoroughly tested in the 20-inch telescope erected in place of the 6-inch refractor. A series of photographs of the *Pleiades*, the *Dumb-bell* nebula, of various clusters, and several photographs of the *Andromeda* nebula were taken with this telescope during the testing of the 20-inch mirrors, but the photographs have not yet been compared and measured. An instrument for rapidly comparing and measuring photographs, as described in the "Observatory," in August 1890, is almost completed, and will be used for a full examination of these photographs as well as for those taken with the 5-foot reflector.

A long series of experiments on the photographic determination of the reflecting power of silver, speculum metal, and silvered-glass surfaces (prepared by different silvering processes), and on the reflecting and transmitting power of plain glass have been carried on, but are not yet completed. The results will be communicated to the Society as soon as the experiments are concluded. A number of trials have also been made of various silvering processes, and a new process has been adopted by means of which a perfect film of any required thickness can be formed with absolute certainty, and mirrors of any size can be silvered with ease and rapidity.

The scarcity of good nights, partly due to the nearness to London, limits the use of the large telescope very much, and it is in contemplation to remove it to some more suitable position.

Mr. E. Crossley's Observatory, Bermerside, Halifax.

The refiguring of the 3-foot mirror is not yet completed. As in past years the occasional measurement of double stars, the meteorological observations and reports to the Registrar-General,

&c., transits for time, and the observation of the phenomena of *Saturn's* satellites and lunar occultations have formed the principal work of the Observatory. The double-star measures and some other observations are being prepared for publication.

Wolsingham Observatory (Rev. T. E. Espin's).

During the past year the work of sweeping for stars of the third and fourth types has been continued. The weather during the spring was unusually bad, and very little could be done. The few fine nights were mostly taken up with spectroscopic work in connection with the new edition of the Red Star Catalogue. The total number of new third-type stars detected in the year is seventy-six; of fourth-type stars four are believed to have been detected, but three of them are so faint as to leave some uncertainty about their classification. Bright lines have been detected in the variable stars R *Aurigæ* and S *Coronæ*. Special study has been made of the spectra of R *Coronæ* and R *Scuti*, and the results have already been communicated to the Society. The final revision of the proof-sheets of the new edition of the Red Star Catalogue was completed in the spring, and the work has since been published by the Royal Irish Academy. During the month of November two new variable stars were discovered. These are:

		h	m	s	°	′	
(1)	D.M. + 33°470	2	30	22,	+ 33	47·1	(1890)
(2)	D.M. + 53·2684	21	37	6,	+ 53	49·4	„

The second is a fine red star, with a remarkable third-type spectrum.

In December Miss E. Brooke presented to the Observatory a fine barograph, by Redier, of Paris, a standard barometer, max. and min., wet and dry bulb and grass thermometers, rain-gauge and rainband spectroscope. The library has been enriched by many valuable presents from observatories at home and abroad. The instruments continue in excellent condition.

Dr. Huggins' Observatory.

The chief work during the past year may be arranged under the following heads:—

(1) A re-examination of the position and character of the chief line in the spectrum of *Orion* and some other nebulæ, with results confirming our former conclusions.

(2) Further photographs of the spectrum of *Orion*, which differ from those described in our last report in containing in addition four and probably five of the lines of hydrogen beyond G, and other new lines.

(3) Two photographs of the spectrum of *Sirius*, which show a new group far on in the ultra violet. It consists of six new lines, which have been measured.

(4) An examination of the Wolf-Rayet stars in *Cygnus*, and direct comparisons of these stars with the hydrocarbon flame, sodium, and hydrogen. The blue band was found not to be due to carbon.

(5) An examination of a number of the more characteristic stars of Vogel's class III*a*. A comparison of them with many terrestrial substances. The view taken of them by Dr. Huggins in 1864 was confirmed.

(6) Observations of the character and extent of the continuous spectrum of the Great Nebula in *Andromeda*. Dr. Huggins' suggestion in 1864, that the apparent ceasing of the spectrum in the orange may be due to the falling off of the eye's power for this part of the spectrum, has been found to be the true explanation. With a suitable prismatic arrangement the red end was distinctly seen.

Rousdon Observatory, Lyme Regis (Mr. C. E. Peek's).

The routine work of the Observatory has been continued. The year 1890 was very favourable for observation except during December, when work was much hindered by abnormally cloudy skies and severe wintry weather. Observations have been made on 161 nights, this being about the average for the last five years. The $6\frac{4}{10}$-inch equatoreal has been employed on observations of variable stars. The working list contains 24 stars, of which 452 observations have been secured. The usual transit observations for time have been made.

Birr Castle Observatory (Lord Rosse's).

During the past year the work of the Observatory has been in the direction of getting ready for publication the observations of past years rather than in undertaking fresh work at the telescope. The drawings of the "Milky Way" are in the hands of the lithographer, and one of the four plates is ready to be struck off. The other three are in progress.

The results of the measurements of lunar heat during the eclipse of January 28, 1888, are now fully reduced, and will, we hope, be brought out shortly.

Some attention has been given to astro-photography with encouraging results.

The meteorological observations for the London Meterological Office have been made throughout the year as usual.

Hong Kong Observatory.

At the end of 1889 this Observatory lost the services of both assistants. One of them went away on sick leave, and the other obtained a better-paid situation elsewhere. In consequence a part of the work was unavoidably stopped, but the meteorological observations, weather reports, and storm-warnings have been continued as heretofore with the aid of the two Chinese clerks.

A commission, appointed by the Governor to examine into the working of the Observatory, subsequently reported that the staff was insufficient, and recommended an annual vote more than double of what was sanctioned hitherto. They suggested that the staff should consist of a director, three assistants, and three native clerks.

A cable has been laid across the harbour for communication with observers at other ports, and for issuing storm-warnings. The Morse apparatus is worked by two native telegraphists in the Observatory, and a telephone line now connects the station on top of Victoria Peak with the city. The direction and force of the wind is telephoned every three hours during the day-time.

The time-service was stopped during the first half of the year, but the time-ball was dropped during the latter half of the year with the assistance of an electric engineer, who was appointed acting assistant. The tide-gauge has been transferred to the Imperial Maritime Customs of China, and it is intended to work it in course of time in each of the ports along the China coast. The magnetic observations have also been interrupted for some time.

Major-General Palmer, R.E., at present in Japan, who in 1882 wrote the report which subsequently led to the establishment of this Observatory, but which unfortunately was not at once fully carried out, gave valuable information before the Commission and drew up a report explaining the necessity for a larger expenditure, which was adopted by the Commission and printed by order of the Governor. There is no doubt that this will increase the immediate utility of the Observatory, which is of great importance to all who trade in the Chinese seas, as Hong Kong is considered the third port in the British Empire, judging by the tonnage of the shipping by which it is frequented.

Melbourne Observatory.

During the year 1890 the meridian work with the transit-circle has been continued as usual, and on the same lines as in 1889.

The great telescope remained dismantled during a considerable part of the year, on account of refiguring and repolishing the mirrors, which was commenced in 1889. At the beginning of last year one mirror was made in a measure fit for work, but the figure was not quite satisfactory. The second mirror was put on the machine in December, and, after continued disappointments and failures, was satisfactorily completed in June, the figure and polish being as good as it appears possible to obtain, and, indeed, leaving little to be desired in either particular. This mirror and its secondary, which has also been repolished, were at once put into position, and the telescope has since been in use for observation. The performance of the great reflector is now certainly better than it ever has been previously. The second mirror (B) also has now been partly refigured, and it is hoped will be in as satisfactory a state as A. The work done with this telescope during the past year has, in consequence of these repairs, been very limited.

All extra-meridian observations have been made with the smaller telescopes, and include spectroscopic survey work and observations of comets.

The usual meteorological and magnetical work has been carried on uninterruptedly during the year, and the intercolonial weather telegraph system now embraces the whole of the coast-line of Australia, as well as a large part of the eastern portion of the interior. Weather charts and forecasts are published in Adelaide, Melbourne, Sydney, and Brisbane, each one for all Australia.

The Melbourne Second General Catalogue of 1211 stars was published in February, and the Monthly Record of Meteorology and Terrestrial Magnetism has been issued up till August last.

Preparations for the approaching work in connection with the photographic star-charting operations have lately demanded attention; catalogues of guide stars have been prepared, many of which will be re-observed with the transit-circle. The astrophotographic telescope and accessories arrived from Dublin on December 29, 1890, and the instrument is now in process of being mounted. Endeavours are being made to secure trial-plates in time to reach Paris by the time the Conference meets in March.

The Board of Visitors in their last report (September 1890) advise the Government to obtain a refracting telescope of 24 inches diameter, to mount on the large reflector as a twin telescope.

The photo-heliograph had for a considerable time been un-

satisfactory in its performance, both as regards permanence of focus and in the exposing slide, and it has been found desirable to make an entirely new arrangement for carrying the secondary magnifier and a new exposing mechanism. These improvements are now completed, and the instrument is in good working order. Owing to these alterations, only sixty Sun pictures have been obtained during the year.

Natal Observatory, Durban.

The work of the Observatory during the past year has been limited by the absence of the director in England for the eight months April to November. In consequence the greater part of the work has been the routine observations required by the daily necessities of the institution.

The work of observing pairs of equi-zenith distance stars for the determination of the latitude of the Observatory has been brought to an end. In all some nine hundred observations of thirty pairs of stars have been secured. It only remains to investigate the exact declinations of the stars used, in order to deduce the true latitude of the Observatory, which forms the second fundamental point of the South African Geodetic Survey.

Considerable progress has been made in the work of comparing, by equi-zenith distances, the declinations deduced from the observations made at the observatories in the northern and southern hemispheres. A revised list of some eighty pairs of stars has been formed, which are observed on every suitable evening.

During the year there has been received the revised comparison of the Greenwich observations for the years 1847 to 1861 with Hansen's *Tables de la Lune*.* The four earlier years, 1847–1850, have been rejected as not being made with the same instrument as those of later years; but the results of the eleven years' observations made during 1851–1861 with the Greenwich transit-circle are being reduced, compared, and discussed in the same manner as those for the sixteen years 1862–1877 in the memoir on the corrections required by Hansen's *Tables de la Lune* in the *Memoirs* of the Society for 1885.

When this work is completed it will afford a continuous comparison of the *Tables* with the Greenwich observations for the thirty-eight years 1851–1888, and the results are sufficiently advanced to show that the corrections deduced will bring Hansen's *Tables* into close accord with the actual place of the Moon, in so far as they will eliminate all the corrections of short periods, which at present give rise to discordances, varying

* *Monthly Notices*, vol. l. Appendix.

in a single lunation by as much as twelve to fifteen seconds of arc.

Some further progress has been made in preparing for publication two elaborate memoirs on the inequalities in the motion of the Moon due to the perturbations of the planets, the first affording an investigation of the theory, and the second a numerical calculation of the value of some thirty-five terms.

Sydney Observatory.

At Sydney the year 1890 has been singularly unfavourable for astronomical work. The rainfall recorded at the Observatory was 81·418 inches, which is, with one exception (1860) with 82·810 inches, the greatest on record. Some measure of this excessive rainfall may be got from the fact that the average at Sydney is 49⅝ inches; but even this does not indicate the amount of cloud, which was far in excess of the proportion which might have been expected for the rain.

The work accomplished in 1890 may be summarised as follows:—

The Transit-Circle.

Number of determinations of Collimation	306
„ „ „ Level	417
„ „ „ Nadir	425
„ „ „ Azimuth	168
Number of observations of stars in R.A.	2021
„ „ „ „ N.P.D.	576

Thirty-nine nights were wholly devoted to observations for determining longitude of places within the colony for the Trigonometrical Survey.

Five hundred and seventy-six stars observed in N.P.D. have been taken with a view to their use in the photographic survey of the heavens. They are for the most part between 20° and 80° south declinations.

The reduction of stars observed in 1888 is finished, and that for 1889 nearly completed.

With the 11½-inch equatoreal only seventy-eight nights were fit for observing; twelve of these were devoted to comet work, and sixty-six to double stars. The work done was as follows:—

Measures of angles of position	685
„ „ distance...	794

The comets observed were Comet *c* 1890, and D'Arrest's Comet.

The observations of double stars in 1890 are completely reduced and ready for publication.

All the unpublished double-star observations were in March collected and reduced and prepared for publication.

Early in the year the construction of the astro-photographic telescope was completed so far as it could be until Sir Howard Grubb sent the object-glass. This arrived at the end of September, and in November the telescope was completed and ready for work; every available fine night has been used in experiments for determining the focus and other matters connected with it, the weather being very unfavourable for this purpose, as, when it was fine, the definition was almost invariably bad. The photographic focus of the lens is about 0·08 in. inside the visual focus, and the defining quality of the objective seems to be all that could be desired.

The mounting is extremely satisfactory, and the great weight (2 tons) of the moving parts give it a stability and freedom from ordinary tremor which is a great help in photographic work.

In April, as the photographic objective had not arrived, experiments were made with a lens from the photo-heliograph, but it was found to be unsuitable for depicting the Milky Way; one of Dallmeyer's largest portrait lenses was then obtained and mounted on the stand of the astro-photographic telescope, and work begun in taking photographs of the Milky Way. Whole plates, $8\frac{1}{2} \times 6\frac{1}{2}$, were used; these cover $14° \times 10°$ of the heavens. Beginning with η *Argûs*, in the centre of one plate, the whole of the Milky Way to β *Triangulum Australis* was photographed; another picture was taken of the constellation *Musca*, and three other plates, one covering the bright part in *Sagittarius*, the others in *Ara* and *Norma*.

Photographs have also been taken of *Nubecula Minor*, exposure in this case lasting 8 hours, and of *Nubecula Major*, 7 hours. The latter reveals a decided spiral structure in this object, and five smaller spirals can be traced round the larger one; and in general outline *Nubecula Minor* is very similar to *Nubecula Major*.

Some work has been done in making a general catalogue of coloured stars in the southern heavens for use in discussing star photographs. 1,200 stars derived from all sources have been included, but the work is not yet completed.

The work of selecting guiding stars for the zone to be photographed at Sydney, 42° to 64°, has been almost completed; as was that for the zone originally allotted to Sydney—viz., 34° to 42°, before the change in the zone was announced.

In October an observing station was established on Red Hill, 615 feet above the sea and 11 miles north-west of the present observatory, with a view of testing its fitness for photographic work. Enough has been proved to show that the position is much better than the city for such work; but the weather

has been so unfavourable that no very long exposures have been obtained. One plate of *Nubecula Major* with 3½ hours' exposure approaches that taken in Sydney with 7 hours' exposure; but it is not equal to it. The instrument used is a 6-inch telescope by Grubb, with the Dallmeyer camera bolted on to the telescope. This camera is the same as that previously used in Sydney.

Arrangements have been made to have the large room on the east of the tower, a part of the building in every respect suitable, fitted up as a library, in addition to the rooms already in part used for books. Serial books have been thoroughly examined, and very many pamphlets and works received in paper covers have been bound.

The report of rain, rivers, and evaporation for 1889, together with the general meteorological results for 1888, have been published and distributed, and the latter for 1889 is in the press.

The reporting rain stations in 1889 numbered 1017; in 1890 the number was 1094.

In March a new gas-engine was obtained, and the system of electric lighting, which had previously been confined to the equatoreal, was extended to the north equatoreal, the transit-circle, and the astro-photographic telescope.

Each instrument has its own group of accumulators; but they are all kept together and charged at one time. It is found that there is very great economy as well as convenience in this arrangement. It has not been deemed necessary to apply the electric light to the library or other rooms; but for the telescopes it is indispensable, and in fact makes it possible to do much work that, without it, is almost or quite impossible.

In explanation of the large number of observations of Level and Nadir, it may be stated that it is the practice to determine these every morning at 9 A.M. with the collimation, in order to test the stability of the piers.

Mr. Tebbutt's Observatory, Windsor, N.S. Wales.

There was much cloudy weather during 1890, particularly in the early months of the year. The adjustments of the 3-inch transit-instrument have been as satisfactory as in former years, but the rate of the sidereal chronometer has not been so good. Eight hundred and twenty-nine star transits, including azimuth stars, have been observed for local time. The following extra-meridian observations have been made, chiefly with the 8-inch equatoreal:—

Twenty-four lunar occultations of stars, comprising twenty-four disappearances and three reappearances.

Phenomena of *Jupiter's* satellites, classified thus:—Transit-ingress, I. 3, II. 2, III. 1, IV. 1. Transit-egress, I. 5, III. 1,

IV. 1. Occultation-disappearances, I. 4, II. 2, IV. 1. Occultation-reappearance, I. 1. Eclipse-disappearances, I. 1, III. 1, IV. 2. Eclipse-reappearances, I. 7, II. 4, III. 4.

Eclipse of the Sun partly observed on December 12.

Seventy-six filar-micrometer comparisons of *Ceres* on May 13, 15, 19, 20, 21, 22, 23, 24, 25, 29; thirty-four of *Juno*, on May 19, 20, 22, 25; thirty of *Ariadne*, on July 21, 22, 23, and thirty-eight of *Undina* on September 8, 9, 10. Three square-bar micrometer comparisons of Denning's Comet on October 4, and ninety-nine of D'Arrest's Comet on October 12, 13, 14, 16, 17; November 1, 5, 6.

Measures of the double stars *p Eridani*, Lalande 4219, *γ Centauri*, *h* 4634, *α Centauri*, Brisbane 5784, and *γ Coronæ Australis*. Determinations of the magnitudes of *η Argûs* and R *Carinæ* on many occasions.

The 9^h A.M. meteorological observations have been carried on as usual, but the tide observations, owing to the disturbed state of the South Creek from frequent rains, have been discontinued. The meteorological observations now extend over a period of twenty-eight years. All the astronomical and nearly all the meteorological observations have been made by the proprietor. The reductions likewise have almost all been executed by him.

Notes on some Points connected with the Progress of Astronomy during the Past Year.

Discovery of Minor Planets.

The following fifteen minor planets were discovered in the year 1890:—

No.	Name.	Date of Discovery, 1890.	Discoverer.	Place of Discovery.
288	Glauke	Feb. 20	Luther	Düsseldorf.
289	Nenetta	Mar. 10	Charlois	Nice.
290	Bruna	20	Palisa	Vienna.
291	Alice	Apr. 25	,,	,,
292	Ludovica	25	,,	,,
293	Brasilia	May 20	Charlois	Nice.
294	Felicia	July 15	,,	,,
295	Theresia	Aug. 17	Palisa	Vienna.
296		19	Charlois	Nice.
297		Sept. 9	,,	,,
298		9	,,	,,
299		Oct. 6	Palisa	Vienna.
300*		3	Charlois	Nice.
301		Nov. 16	Palisa	Vienna.
302*		14	Charlois	Nice.

Minor planets Nos. 283, 284, and 285, discovered by M. Charlois, at Nice, in 1889, have been named, respectively, *Emma*, *Amelia*, and *Regina*. Minor planet No. 286 has been named *Iclea* by the discoverer, Herr Palisa, of Vienna. It may be pointed out that the names of the discoverers of Nos. 285 and 286, as given in the last Annual Report, should be interchanged, the former being credited to M. Charlois and the latter to Herr Palisa.

* These objects were observed for No. 298. They were afterwards found to be new planets. Meanwhile, Nos. 299 and 301 had in each case respectively been discovered and numbered.

The Comets of 1890.

The distinguishing feature in the history of comets for the past year has been the prolonged series of observations effected by the Lick Telescope. Comet I., 1889 (discovered 1888 September 2), was observed 710 days after its discovery, and a still longer series of observations is expected. Comet II., 1889 (discovered March 31), was observed in August 1890, while Comet V., 1889, whose orbit is especially interesting as suggesting a possible connection between it and Lexell's comet, was recovered after a lapse of eight months.

During the year the following comets have been discovered :—

I. On 1890 March 19, Mr. Brooks, of New York, perceived a nebulous object, which a subsequent observation on March 24 showed to be a comet. It was described as a bright telescopic comet, with stellar nucleus and short, wide tail. The character and position of the orbit were such that the comet could remain visible for some months, and probably is still within the range of the larger telescopes. The orbit does not deviate sensibly from a parabola.

II. Discovered by M. Coggia, of Marseilles, on July 21. The comet, though described as tolerably bright at its discovery, grew rapidly fainter, and, remaining an inconspicuous object on the summer sky, appears to have been soon lost. Parabolic elements represent the observations with accuracy, but there is some similarity between these elements and those of the comet of 1580.

III. Discovered by Mr. Donning, of Bristol, on July 23, in the constellation *Ursa Minor*. It was a faint object in a 10-inch reflector. This comet, passing its perihelion on September 24, was increasing in brilliancy, but it seems to have been always a difficult object to observe. The motion in declination carried the comet rapidly to the south, and observations became impossible in the northern hemisphere. This object was then observed with difficulty at Cordova till November. There is no reason to suspect ellipticity.

IV. A reappearance of the comet of D'Arrest, which was first seen at Lick by Professor Barnard, apparently without any assistance from the ephemeris of M. Leveau. A comparison of the observed places with that ephemeris shows that the prediction of the perihelion passage was about one day in error; but inasmuch as the perturbations of *Jupiter* alone had been taken into account, the agreement is satisfactory. The great southern declination of the comet, coupled with its extreme feebleness,

has made it a very difficult object even for large telescopes.

V. On November 15 M. Zona, of Palermo, discovered a very faint comet, and whose brilliancy was diminishing, having passed its perihelion in the previous July. The orbit, which is probably parabolic, is distinguished by its considerable perihelion distance. It has been pointed out by Dr. Holetschek that the brilliancy of the comet was approximately the same in the previous March as at the time of discovery, and more favourably situated for observing with regard to the Sun. The declination, however, was then south, and the object could only have been observed in the southern hemisphere.

VI. While Dr. Spitaler, of Vienna, was searching for the last-named comet, he detected a faint nebulous object near its reported place. The approximate position and direction of motion proved, however, that it had no connection with Zona's comet, but was a new discovery. Through bad weather this object was lost, but on December 4, being assisted by the slow motion of the comet, Dr. Spitaler again picked it up. This re-discovery was fortunate, as the comet has proved to be one of short period—about six years—and probably has but recently entered the system, since in the latter half of 1887 the comet at the descending node approached so closely to *Jupiter* that it must have undergone very serious perturbation. The orbit is still very uncertain.

It is to be regretted that neither of the two periodic comets, Brorsen's and Denning's, have been seen at their recent return to perihelion. There is no adequate explanation of the non-appearance of the first of these, since the circumstances of its return were favourable for observation, and it was sought for by powerful instruments in the hands of experienced observers. That Denning's comet escaped is not remarkable. The orbit is very uncertain, and, while the comet is intrinsically faint, the probable date of its perihelion passage determined a path unfavourable for observation. W. E. P.

The Transits of Venus in 1761 *and* 1769.

The observations of the transits of *Venus* in 1761 and 1769 have been so repeatedly and thoroughly examined and discussed by so many who were eminently qualified for the investigation, that it might be thought there remained but little opening for arriving at any different values for the solar parallax from these observations than those already published.

The classical work of Encke on the subject was considered to result in the most reliable value of which the observations were capable of affording. But his investigation, like the earlier ones of Lalande and De Ferrer, and the more recent work by Mr. Stone, as well, indeed, as the discussion of the late transits of 1874 and 1882, all depend upon the interpretation to be put upon the phenomena of contact recorded as having been witnessed by the observers.

Conceiving that the numerous observations of 1761 and 1769 were capable, under the light thrown upon these phenomena at the recent transits, of a different interpretation to that hitherto accepted, Professor Newcomb has made a new and complete discussion of those observations, from which he derives a value for the solar parallax differing very widely from that deduced by Encke. This interesting and important investigation has recently been published as part v. of vol. ii. of the *Astronomical Papers prepared for the use of the American Ephemeris and Nautical Almanac.*

In the introductory portion of the work Professor Newcomb explains the reasons which have actuated him in undertaking the present discussion. The exaggerated opinion of the accuracy with which transits of the inferior planets could be observed has led to a too free rejection of discordant observations, and produced an undue bias in favour of those which were in good agreement. It having been found that the results thus obtained were erroneous to an extent not supposed possible, a tendency has resulted to look upon them as too inaccurate for further discussion. But, admitting a probable error of the observed times of contact ranging from 10 to 30 seconds, he considers that this forms a fair basis from which to judge them, and if the solar parallax derived from them prove of little value, yet the material for the determination of the motions of *Venus* and the Earth would be alone worth the discussion. On the subject of the phenomena of contact the author states the general theory upon which all preceding discussions were founded to be—

"Firstly, that the formation of the thread of light at ingress and its breaking at egress mark the true time of tangency of the dark limb of *Venus* with the bright limb of the Sun.

"Secondly, that a definite interval intervenes between this formation or breaking of the thread of light and the moment known as apparent or geometric contact of the limbs, which interval arises from and depends upon irradiation.

"Neither of these propositions," he remarks, "is a sufficient approximation to the truth." "The time of formation of the thread of light at ingress can be no other than the moment when the thread grew sufficiently strong and well marked to be seen by the observer." Obviously depending upon telescopic power and atmospheric conditions. "The earlier the time when the observer saw the breaking of the thread of light at egress, the later he would note the apparent geometric contact. The

clearer and steadier the air and the sharper the vision, the more nearly the two phases would approach each other, until, under the best conditions, they should come together."

In considering the observations the author divides them into three classes.

(1) Those in which the formation or extinction of the thread of light is stated to have been observed.

(2) Cases in which some phenomenon of contact was noted earlier than the formation of the thread of light at ingress or later than its disappearance at egress.

(3) Observations in which no statement is made from which it can be inferred that one phase rather than the other was observed.

In considering the difficulty of combining such observations, Professor Newcomb was led to adopt Encke's original system of interpretation, which was that the presumption was in favour of the thread of light unless some evidence was shown to the contrary.

That being so, it is certainly surprising that the result of 8″·79 which he obtains for the solar parallax should differ so much from the well-known value 8″·571 obtained by Encke. It is perhaps a little unsatisfactory that the author is not prepared to explain how this great difference comes about. Some suggestions are made as to the possible causes of the discrepancy, such as the fact that at the northern stations the Sun was near the horizon, so that the observed ingress was too late and egress too early compared with the southern. The weights assigned to the observations may prove a possible source of difference. Professor Newcomb does not accept the interpretation of Cook's and Chappe's observations proposed by Mr. Stone which led him to the value of 8″·91. A third source of difference may be the more accurate modern determinations of the longitudes of the stations.

Throughout the investigation, any comparison with Encke's work which might bias the author's judgment has been avoided.

The second chapter of the work is devoted to a citation, with some discussion, of all the recorded observations of the transit of 1761, and, so far as practicable, a copy of the original record pertaining to each separate observation is given. One testimony is rendered to the completeness of Encke's work in collecting observations: the author states that, having desired to proceed independently, he soon found that nothing which he could discover had escaped Encke's scrutiny.

The third chapter gives, in the same manner, the observations of the 1769 transit, of which one interesting section gives a complete transcription of the much-doubted observations of Father Hell, at Wardhus, the mystery of which, however, was satisfactorily cleared up by Professor Newcomb, in a paper published in vol. xliii. of the *Monthly Notices*. From his own

careful examination of Hell's original MS. notes, he concludes that "whatever the sources from which the corrections were derived, the numbers as printed by Hell were all but one or two obtained at Wardhus."

The fourth chapter is devoted to the geographical positions of the stations, in which the longitudes of all stations not determined by modern methods are separately discussed. A table of the adopted geographical positions is appended.

In the fifth chapter the tabular elements to be corrected by observation are discussed, and tabular times of contacts are given for the phases I., II., III., and IV. for both transits at all the stations. In the following chapter the observations are compared with the tabular times. The tabular summary of observations gives, in a very interesting manner, several details: the kind of observation and the phase to which it belongs, the kind of telescope used and its focal length, and the Sun's altitude at the time of observation.

In the formation and solution of the equations of condition, some novelty in treatment is necessitated by having to deal with a collection of observations made under widely different conditions, and therefore of very different moduli of precision.

In such cases Professor Newcomb points out that the method of least squares, as usually applied, will not give the best results. By a graphical process he exhibits the law of the residuals in magnitude for interior contacts. The residuals are classified as if multiples of five seconds, the nearest multiple being assigned. The first column of a table contains the multiples of 5^s from -75^s to $+75^s$. Opposite each multiple is printed as many I's as there are residuals having a magnitude differing not more than two seconds from that multiple. In discussing this table, the conclusion is arrived at that, making no rejection whatever of results on account of discordance, unfavourable conditions, or unskilfulness, the probable error of a single observation is less than $\pm 15^s$. Residuals without the limits -67^s and $+67^s$ are rejected. The questions are discussed of an expression for irradiation and other imperfections of vision, altitude of the Sun, size of telescope, and magnitude of the black drop.

A table gives the estimated numbers expressive of the irradiation at first interior contact.

The considerations of the weight to be assigned to the observations is examined in detail.

In the equations of condition a coefficient is introduced which depends upon the effect of the imperfection of vision, and has a special value for each phase.

The final discussion of the results yields for the solar parallax the value $8''{\cdot}79$, with a mean error of $\pm 0''{\cdot}051$, and a probable error of $\pm 0''{\cdot}034$.

Professor Newcomb concludes this most interesting investigation by a discussion of the position of the node of *Venus*, and gives the following corrections:—

Correction to Le Verrier's latitude of *Venus* at descending node for mean of 1761 and 1769 ... ... + 1″·915

and

Correction to Le Verrier's longitude of the node 1765·5 +32″·4

M. Tisserand's "Traité de Mécanique Céleste," Tome II.

During the past year has appeared Vol. II. of M. Tisserand's *Traité de Mécanique Céleste*, of Vol. I. of which an account was given two years ago in the Report of the Council. The present volume deals with the forms and the rotations of celestial bodies. The first part of the book is confined to the forms, and this subject is fully dealt with so as to include the results of much recent work. The figures of the Earth, of the Moon, and of *Saturn's* ring are particularly treated of. A chapter is devoted to giving a short account of the geodesical mode of determining the figure of the Earth, and the results which have been derived from it; and this part of the volume closes with Chapter XXI., on the Earth's figure as determined by pendulum observations.

The last part of the work treats of the rotation of the heavenly bodies, especially of the Earth and Moon. Precession, nutation, and the possible changes of the axis of the Earth, and the rotation and libration of the Moon are all treated of; and the volume closes with two chapters on the rotation of a body of variable form, which introduces the effects of geological changes on the Earth, want of rigidity of its crust, secular cooling, tidal retardation, and finally it treats of the effects of lunar and solar attraction on the plumb-line.

M. Tisserand not only gives references to the authors whose researches he embodies or gives an account of, but he gives at the end of each subject a list of works where the student may meet with further information.

M. Tisserand mentions in the preface that he is absorbed in preparing Vol. III., which, therefore, we trust to be in a position to notice in an early Report. J. F. T.

Recent Researches on the Solar Motion.

The method by which the amount and direction of the solar motion has recently been discussed by Professor Boss * and by Herr Stumpe † differs in some important particulars from the many determinations of these constants that have already

* A determination of the Solar Motion, by Prof. Lewis Boss, *Astronomical Journal*, Nos. 195, 196.

† Untersuchungen über die Bewegung des Sonnensystems, von Oscar Stumpe, *Ast. Nach.*, Band 125, No. 3000.

appeared. In the first of the two papers under consideration Professor Boss has rested his inquiry on the proper motions of stars confined to a narrow zone whose breadth is only 4° 20′, and whose mean declination is 3° North. This is the zone which, under the general scheme of the re-observation of Argelander's stars, has been assigned to Albany, New York. Two advantages are gained by the employment of stars in a narrow equatorial zone such as that here used. One is, that if slightly incorrect precession constants be employed, the determination of the solar motion will not be affected, supposing the stars to be uniformly distributed throughout that zone. The other advantage is that the stars are very nearly symmetrically arranged with reference to the co-ordinates of that motion. This fact greatly facilitates the solution of the problem by simplifying the expressions used. It is, however, accompanied by the disadvantage that no correction to the precessional constant in declination can be determined.

Another feature in the work of Professor Boss is the large amount of new material introduced into the discussion. Out of about 250 proper motions employed, only 49 are known to have been used in a similar research. The derivation of these new proper motions has necessitated a rigorous discussion of the systematic differences that exist between the various catalogues employed in their determination, and this portion of the work has been undertaken by Professor Boss with very great care, and the resulting proper motions will, no doubt, command confidence. As illustrating the systematic differences that are to be found between catalogues generally accepted as of fair accuracy, it may be mentioned that if the stellar positions given in the zones of Lalande and Bessel, uncorrected to any general system, be compared with modern results, systematic annual proper motions of $0^{s}\cdot005$ in R.A. and $0''\cdot05$ in declination may be expected.

Professor Boss makes no assumption as to the probable distance of the stars as indicated by their proper motion or magnitude, but, after rejecting a few instances of unusually large motion, he groups the remaining stars whose motions exceed $0''\cdot10$ in the arc of a great circle, in order of right ascension, about one hour to each group. The position of the direction of the solar motion is found, first, by solving the equations of condition furnished by stars brighter than the eighth magnitude; secondly, by those fainter than the eighth; and thirdly, in one entire group independent of magnitude. These three solutions furnish the following values of the constants sought:—

Series.	Mean Magnitude.	No. of Stars used.	Apex of R.A.	Solar Motion. δ	Centennial Solar Motion.
			°	°	″
1	6·6	135	280·4	+42·8	12·39
2	8·6	144	285·7	+45·1	13·73
3	7·6	279	283·3	+44·1	13·09

Since there was reason to think that the resulting direction and amount of the solar motion were injuriously affected by the presence of large proper motions, those exceeding 100 seconds a century were rejected, and the remainder (253 in number) formed into one group, with a mean magnitude of 7·7, gave the following result:—

$$\text{R.A.} = 288^{\circ}\cdot7 \pm 7^{\circ}\cdot2$$

$$\delta = +51^{\circ}\cdot5 \pm 3^{\circ}\cdot2$$

Centennial motion... $10''\cdot58 \pm 0''\cdot60$

The computations of Herr Oscar Stumpe are based on the proper motions of 1054 stars whose annual proper motions exceed $0''\cdot16$ in the arc of a great circle. The stars used have been taken from Bradley's Catalogue, as reduced by Auwers, from Argelander, and from other miscellaneous sources, the whole of the material having been submitted to a searching investigation. The peculiar feature in the treatment is the modification of Airy's equations, necessitated by the addition of a term $(d\,l)$ depending upon a supposed orbital motion of the stars in the plane of the Milky Way. On this hypothesis a variation of the galactocentric longitude of the stars may be considered as real, whilst the alteration of the latitude and radius vector must be attributed to chance errors. As a matter of fact, the solution of the equations of condition showed that the term $(d\,l)$ was zero, and in the results given below has been treated as such.

The stars have been divided into four groups depending on the amount of the annual proper motion, which was thought to offer a surer guide to the relative distances of the stars than could be concluded from their magnitude. The limits of proper motion of each group, and the number of stars employed, is shown below:—

Group.	Limits of Prop. Mot.	No. of Stars in Group.	Mean Prop. Mot. of Group.	Mean Magnitude.
I.	$0''\cdot16-0''\cdot32$	551	$0''\cdot23$	6·0
II.	$0\cdot32-0\cdot64$	340	$0\cdot43$	6·7
III.	$0\cdot64-1\cdot28$	105	$0\cdot85$	6·1
IV.	$1\cdot28$	58	$2\cdot39$	6·5

The equations of condition founded on each group have been separately solved, thus affording four independent determinations of the amount and direction of the solar motion. The agreement in the resulting co-ordinates is very satisfactory, and the amount of solar motion as determined from each group varies directly with the proper motion, affording satisfactory evidence that the selected criterion of distance—viz., the annual proper motion—was warranted. The results are as follows:—

Group.	α	δ	Annual Motion.
	°	°	″
I.	287·4	+42·0	0·140
II.	279·7	+40·5	0·295
III.	287·9	+32·1	0·608
IV.	285·2	+30·4	2·057

In the last column the annual motion is the maximum angular value as viewed from the mean distance of each group.

The result of these and of other recent investigations into the direction of the solar motion has been to indicate a point in the heavens considerably north and east of that assigned in the earlier discussions. It would seem that the direction would be more accurately described as towards *α Lyræ* than to the generally-quoted stars in *Hercules*. W. E. P.

Schiaparelli's Researches on the Rotation of Venus and Mercury.

The periods of rotation of the two inferior planets have been determined from time to time by several observers, but never in a satisfactory manner. The researches of Professor Schiaparelli, lately published in the *Rendiconti del R. Istituto Lombardo*, vol. xxiii., and in the *Ast. Nach.*, No. 2944, are therefore of great interest, the more so as the results have been altogether unexpected.

The earliest observer who detected surface markings on *Venus* seems to have been J. D. Cassini. He was inclined to conclude that the planet rotated in 23 *days*, but he expressed himself very guardedly, and pointed out the diffused appearance of the spots, which made the observations very difficult. Many years afterwards his son made out from the same observations and those of Bianchini, that the period of rotation was $23^h\ 20^m$, though Bianchini himself had come to a very different result. Employing various telescopes by Campani, he observed in 1726–27 a number of markings of an apparently permanent character, from which he constructed a complete map, and found the rotation period equal to 24 days and 8 hours. Professor Schiaparelli, in a detailed discussion of all the earlier physical observations of *Venus*, points out that Bianchini himself acknowledged the difficulty of seeing the dark shades, which, according to his drawings, were only visible along the terminator and never in the middle of the illuminated part of the disc. An examination of Bianchini's map (which is reproduced in the *Ast. Nach.*, No. 278) also shows that the seven dark markings distributed along the equator are all similar in appearance, so that they have only resulted from a perfectly arbitrary combination of the drawings, and the theory was never tested by observing the spots when they ought to have appeared at a distance from the terminator.

More weight has generally been attached to the observations of Schröter, who depended less on the faint shades occasionally seen by him than on a truncation of the southern cusp, the changing appearance of which he believed to be irreconcilable with a slow rotation. He determined the period equal to $23^h\ 21^m\ 0^s$, which value, however, as remarked by Schiaparelli, does not represent the alleged changes well. Various observers have subsequently noticed similar irregularities in the shape of the cusps, but nobody after Schröter has attempted to deduce a rotation period from them. A new investigation of this problem by observations of dark markings was made in 1839–41 by De Vico, who made use of ten thousand measures of difference of declination between spots and the north or south limbs of the planet. The results were, however, unsatisfactory, and finally he combined some of the best observations made at the Collegio Romano with two of Bianchini's, and thus found a correction to Schröter's period, making it $23^h\ 21^m\ 21^s{\cdot}9345$.

Professor Schiaparelli remarks that from Jacques Cassini down to De Vico, the period $23^h\ 20^m$ has been maintained by a series of illogical and illusory conclusions, which can only be compared to those by which the imaginary "trepidation" of the equinoxes was upheld for many centuries.

The observations on which Professor Schiaparelli's investigation is founded were made by him with the 8-inch refractor at Milan, between November 5, 1877, and February 7, 1878, when *Venus* was very favourably situated, being at the greatest eastern elongation on December 11. From December 9 and for about a month a dark shade was seen stretching from the southern cusp in a north preceding direction, but more conspicuous were two small oval and very bright spots, separated by a dark band, and situated close to the southern cusp. A similar phenomenon had been seen at Bothkamp in 1871, and one of the two bright spots was in 1877–78 also seen by Holden, Niesten, and Trouvelot. When *Venus* was followed for some hours at a time the shade and bright spots were seen to remain immovably fixed in the position occupied by them at the beginning of the observation, neither could any change be seen from day to day. On December 15 a drawing was made by Professor Holden at Washington eight hours after Professor Schiaparelli had observed the planet, and yet the two drawings place the principal bright spot in the same place. This shows clearly that *Venus* cannot revolve in 23 hours, and it also disposes of Bianchini's period, as the spot, according to this, should have reached the terminator in less than a day and a half. The values found by Bianchini and De Vico for the inclination and ascending node of the equator of *Venus* on the ecliptic are also shown to be quite erroneous, as they would have made the spots describe wide elliptic paths on the visible part of the disc. The Milan observations can only be reconciled with a period of rotation of between six and nine months, round an axis inclined

at most 12°·9 to the orbit of *Venus*, and Professor Schiaparelli therefore naturally concludes that the rotation takes place in 225 days, the period of revolution of *Venus* round the Sun, and that the axis of the planet is very nearly perpendicular to the orbit. These conclusions are shown to be in perfect accordance with observations by Gruithuisen (1813–14), and Denning (1881).*

Encouraged by these important results, Professor Schiaparelli turned his attention to *Mercury*, which planet he has observed from 1881 to 1889, first with the 8-inch, afterwards with the 18-inch refractor of the Brera Observatory, making in all 150 drawings, which show markings far better defined than the fleeting shadows on the surface of *Venus*. Most of the observations were made in 1882–83, when *Mercury* was followed through seven consecutive synodical revolutions; the daytime being found most suitable for observing, as the planet after sunset was too near the horizon to allow magnifying powers above 200 to be used. The planet could be followed throughout its synodical revolution, except for nearly a month about the time of lower conjunction, and for a week at the upper conjunction. The spots could even be well seen when the planet was only 3° from the Sun, with an apparent diameter of 4″ or 5″. As in the case of *Venus*, the spots were always found in the same places, even after a lapse of several days. That the planet does not revolve in six, twelve, or twenty-four hours became evident when it was followed for many hours at a time without exhibiting any change, and Schröter's period of $24^h\ 0^m\ 52^s{\cdot}97$, determined on very slender evidence, similar to that which he made use of in the case of *Venus*, could thus at once be dismissed. A comparison of all the drawings appears to show that the aspect of the spots is always the same in similar positions of *Mercury* with regard to the Sun and the Earth, so that the rotation would take place in 88 days, in which time the planet makes one sidereal revolution round the Sun. All the observations (1882–89) do not exclude the possibility of a difference of $\frac{1}{1000}$ between the two periods, but probably they are identical. The planet's axis seems to be very nearly perpendicular to the orbit. As the rotation is uniform, and the eccentricity of the orbit is very considerable, a libration of 47° in longitude takes place, so that points along an arc of 227° of the equator of *Mercury* can be illuminated by the Sun, while $\frac{2}{5}$ of the surface never receive light from the Sun.

Professor Schiaparelli's paper (which is to be followed by a detailed account of his observations) is accompanied by a map of the visible part of *Mercury*. The spots are chiefly of a streaky appearance, and seem to be of a permanent character; bright spots are occasionally seen, particularly near the north pole,

* Observations made at the Nice Observatory from May 15 to Oct. 4, 1890, fully confirm Prof. Schiaparelli's results. M. Perrotin finds that his observations can only be represented by a period of rotation from 195 to 225 days. (*Comptes Rendus*, Oct. 27.)

which is generally brighter than the regions around the south pole; and this perhaps explains why the latter to Schröter appeared truncated. As the spots are never seen near the limb, the atmosphere would seem to be very dense. J. L. E. D.

Determination of the Mass of Saturn from Observations of Titan with the Yale Heliometer.

The mass of *Saturn* obtained by Bessel with the Königsberg heliometer from observations of *Titan*, and that obtained by Prof. Hall with the Washington refractor from observations of *Titan* and *Japetus*, differed considerably. A new determination with the Repsold heliometer at Yale was accordingly undertaken by Mr. Asaph Hall, jun., from observations of *Titan* made by him during the oppositions of *Saturn* occurring in the years 1885–86 and 1886–87, and has been published in the *Transactions of the Astronomical Observatory of Yale University*, vol. i. part ii. During this period the ring was opened out to nearly its widest extent, and *Titan* could be brought quite accurately to the extremities of the major axis of the ring-ellipse. Accordingly, Mr. Hall's measurements were all made in this way, as were most of Bessel's. A complete set of measures consisted of sixteen pointings, symmetrically arranged, including reversion of the scales and of the prism eyepiece—the major axis of the ring-ellipse being kept apparently horizontal by means of the prism eyepiece. The position-angle was read at the same time as the distance. Observations of various zones of stars were made during the progress of the work for the determination and control of the instrumental constants; so that the "scale-value," as well as the division errors of the scales and the other instrumental errors, were determined with the most elaborate care.

From the observed distances and position-angles, referred to the east end and west end of the major axis of the ring-ellipse, the rectangular co-ordinates of *Titan* referred to the centre of *Saturn* were computed, it being assumed that the centre of *Saturn* coincides with the middle point of the major axis of the ring. In the discussion of the measures these rectangular co-ordinates were compared with rectangular co-ordinates computed from Bessel's first determination of the elements of *Titan* as given in the *Ast. Nach.* Bd. xi. page 1, and thus equations of condition were formed, by Bessel's method, the solution of which furnishes corrections to the assumed elements of the orbit.

Using the expressions for the periodic corrections depending on the Sun and for the reduction of the mean elements given by Hermann Struve in *Supplément I. aux Observations de Poulkova*, the Yale mean elements found from the two oppositions, reduced to 1886 May 1·0, Paris mean time, are:—

	1885-86.	1886-87.
Epoch	247° 5′·38 ± 0′·669	247° 3′·98 ± 0′·906
Perisaturnium ...	274 15·02 ± 9·158	274 35·42 ± 15·095
Ascending Node	168 12·84 ± 1·471	168 18·13 ± 2·077
Inclination ...	27 39·42 ± 0·665	27 43·03 ± 0·941
Semi-axis Major	176″·599 ± 0″·0263	176″·501 ± 0″·0405
Eccentricity ...	0·029253 ± 0·0001423	0·029359 ± 0·0002250

The most important correction to Bessel's elements is that to the Perisaturnium. H. Struve, in the paper referred to above, found a correction of +50″ per annum to the motion of the Perisaturnium as given by Bessel. If, however, the difference between Königsberg and Yale be ascribed wholly to error in Bessel's value of the motion, an increase of +80″ per annum to that motion is obtained.

The final value of the semi-axis major, found by combining the results of the two oppositions, is 176″·570 ± 0″·0243; the corresponding value of the reciprocal of the mass of *Saturn's* system is

$$\mu = 3500{\cdot}5 \pm 1{\cdot}44.$$

It is shown by H. Struve that the corrected value of μ found by Bessel from *Titan* should be 3502·5 ± 0·77, while the values found by Struve himself from *Japetus* and *Titan* are respectively 3500·2 ± 0·82 and 3495·7 ± 1·43, all of which are in substantial agreement with the Yale value. Prof. Hall, using the great Washington refractor, found from *Japetus* 3481·2 ± 0·65 and 3481·4 ± 0·97, and from *Titan* 3496·3 ± 1·84 and 3469·9 ± 1·49; the first value in each case being found from observations of differences of R.A. and decl., and the second from observations of distances and position-angles. "Although the difference in the values found for *Titan* might lead one to suppose an error in the value of a revolution of the micrometer-screw, the remarkably good agreement found by the two methods from *Japetus* would not sustain this view, and no reason for the discrepancy is very apparent."

Saturn and its Ring.

During the year which has but recently closed a very valuable monograph on the Saturnian System has reached this country, in the shape of Appendix II. to the *Washington Observations*, 1885. It is entitled "Saturn and its Ring," and contains a detailed account of observations and measurements of the planet made by Prof. Asaph Hall from 1875 to 1889 inclusive, together with his deductions from them; the instrument

employed being the well-known 26-inch refractor of the United States Naval Observatory, with which the satellites of *Mars* were originally discovered. In 1876 a very notable white spot made its appearance near the planet's equator. Notice of this was given to various observatories on the American continent, and the spot was seen by several observers. Prof. Hall selects nineteen observations made in various localities (including, of course, his own) when this spot was actually central on the planet's disc, and from a discussion of them all arrives at the conclusion that the period of *Saturn's* rotation is $10^h\ 14^m\ 23^s{\cdot}8 \pm 2^s{\cdot}30$ mean time. It will be remembered that Sir William Herschel determined the time of rotation to be $10^h\ 16^m\ 0^s{\cdot}4$. Very little that was remarkable, save the spot to which reference has just been made, was seen on the ball of the planet, which near the poles has always seemed of a dull grey with a few faint stripes. Save in 1876, and again during a doubtful interval in 1878, the curvature of the shadow of the planet on the ring always followed the outline of the ball; but during the former (and possibly the latter) year the convexity was turned towards the ball. No notch could ever be detected in the outline of the shadow, nor was any real division ever seen between the dusky ring and the one immediately outside of it. Moreover, Prof. Hall could never perceive the so-called Encke's division of the outer ring as an actual division, "notwithstanding especial pains were taken to do so." Sometimes a kind of marking was noticed, but nothing more. An elaborate series of measurements of the ball and ring of the planet afford results which are probably more accurate than any others which we now possess, but their reproduction is needless here. One very important result must, however, be referred to in conclusion. It is this. In 1851 Struve, discussing the observations of the ring made prior to that date, arrived at the startling conclusion that the ring was seemingly undergoing a secular change, which, by the year 1976, would bring its inner edge into actual contact with the surface of the planet. This theory was adopted by Maxwell and by Hirn in their mechanical investigations into the constitution of the ring. But Prof. Hall, from a comparison of his own measures with those of Bradley, Herschel, Encke, and both the Struves, comes to the conclusion that no change has occurred in the dimensions of the ring-system, at any rate since 1719, so that the catastrophe foreshadowed by Struve is a wholly visionary one. W. N.

Dr. Hermann Struve's Researches on Saturn's Satellites.

In No. 2983–84 of the *Astronomische Nachrichten* Dr. Hermann Struve gives an account of some highly interesting preliminary results which he has deduced for the innermost satellites

of *Saturn*. The great optical power of the 30-inch Pulkowa refractor, the steadiness of its mounting, and the goodness of its measuring apparatus allow the observer to measure the mutual positions of *Saturn's* inner satellites, even of *Mimas*, with very great accuracy, and thus to obtain the means of entering upon the proper investigation of their orbits with fair prospects of success. While the observations indicate that the deviations of *Enceladus* and *Dione* from the plane of *Saturn's* equator can be only small, they give for the inclinations of the orbits of *Mimas* and *Tethys* the values 1° 26′ and 1° 5′, and for the annual retrograde motions of the nodes about 365° and 72°. As the sums of these motions of the nodes is approximately equal to double the difference between the mean motion of *Mimas* and twice that of *Tethys*, the consideration of the effect of this approximation to equality upon the elements of the orbits has enabled Hermann Struve to find the probable clue to the puzzling problem of accounting for the variations in the motion of *Mimas*, which were indicated by preceding observations, and which are further proved by the addition of his own. He accounts for these apparent variations by a libration of great amplitude due to the cause indicated, and proceeds to deduce approximate values of the period and amplitude of this libration from the scanty material which is available. As a plausible approximation he assumes 68 years for the period and 97° for the amplitude. The scattered measurements and estimated positions of *Mimas*, made by Bond, 1848–1849 and 1852, and published in 1857 in vol. ii. of the *Annals of the Observatory of Harvard College*, seem to have been overlooked, and will furnish some additional serviceable evidence. But the lack of sufficient trustworthy observations in the past, which, it must be owned, is due to neglect as well as to inadequacy of means, can now only be made good in course of time, and another revolution of *Saturn* will probably have to elapse before the large libration of *Mimas* and the corresponding moderate one of *Tethys* can be worthily determined. From his observations of *Enceladus* Struve finds that the eccentricity of the orbit amounts to about 0·0047, and that the line of apses progresses annually about 120°, which is approximately equal to the difference between twice the mean motion of *Dione* and the motion of *Enceladus*. It remains to be seen whether the inference that this equality is a real one, and that *Enceladus* when in conjunction with *Dione* will also always be near the lower apsis of its orbit, will be confirmed by further observations. It is very satisfactory that we may now reckon upon steady progress in our knowledge of the interesting system of *Saturn*.

A. M.

The Star Catalogue of the "Astronomische Gesellschaft."

Three instalments of the extensive and important Catalogue of Stars, to the 9th magnitude inclusive, situated between +80° and −2° declination, for the epoch 1875·0, observed and reduced at various observatories under the auspices of the *Astronomische Gesellschaft*, have been published during the past year. These parts are:—

(1) Third Part.—Zone +65° to +70°, observed at Christiania.
(2) Fourth Part.—Zone +55° to +65°, observed at Helsingfors and Gotha.
(3) Fourteenth Part.—Zone +1° to +5°, observed at Albany, U.S.

(1) The Christiania Catalogue contains 3949 stars between the limits of north declination 64° 50′ and 70° 10′, taken from the *Durchmusterung* and Lalande's *Histoire Celeste*.

The observations for this Catalogue were made in the years 1870 to 1881 with the Ertel 3-foot meridian circle, the telescope of which has an aperture of four inches.

The observations of right ascension were made by the eye and ear method by the late Professor Fearnley, the declination circle being read by means of two verniers by Dr. Geelmuyden. These methods of observation give good results, for the authors deduce a probable error in R.A. of $0^s.054$, and in declination of $0''.54$ for a catalogue place.

The third term of the precession formula for each star is given in the catalogue of this zone.

(2) The observations from which the Catalogue places were formed were made at Helsingfors during the years 1869 to 1876, and at Gotha during the years 1877 to 1880. The removal of Professor Krueger from Helsingfors to Gotha in 1876 did not require any change of instrument, and does not appear to have impaired the unity of the system of observations. At both observatories an 8-foot transit instrument of 66 Paris lines aperture, fitted with an auxiliary arc of 15 inches radius, was used. All the transits were observed by the eye-and-ear method. Professor Krueger finds for the probable error of a single observation—

At Helsingfors	±0ˢ·101 in R.A., and	±0′·51 in Dec.
At Gotha ...	±0·125 „	„ ±0·76 „

for a mean declination of 60°, and three or four transit threads. In these observations it appeared that the brightness of the star produced no sensible effect on the observed time of transit.

All the stars in the *Durchmusterung*, down to mag. 9·1 in-

clusive, were entered in the Helsingfors-Gotha working list, and all these, with few exceptions, were observed twice at least. Professor Krueger furnishes a table for correcting the secular variations on account of proper motion for 258 stars of the Catalogue for which alone this effect is sensible. A special table for computing the third term of precession, with arguments at intervals of 10^m in R.A., and of single degrees in declination, is also given. The total number of stars whose places are given in this Catalogue is 14,680.

(3) The Albany Catalogue gives the places of stars deduced from observations made at the Dudley Observatory, during the years 1878 to 1882, by Professor Boss. The instrument used at Albany was the meridian circle of the observatory of 8 inches aperture. In the zone work the transits of standard stars were observed over fifteen threads, and for these stars all four microscopes were read, whilst for the zone-stars five threads and one microscope were employed. The transits were all observed chronographically.

The probable error of a single observation, for the zone-stars, is $\pm 0^s{\cdot}036$ in R.A., and $\pm 0''{\cdot}55$ in declination, corresponding to the mean declination of the zone. A special investigation on the effect of brightness of a star on the observed time of transit shows that the R.A.s of the Catalogue require the correction

$$-0^s{\cdot}0087\,(M-4)-0^s{\cdot}00166\,(M-4)^2,$$

where M is the magnitude of the star observed.

The position of each star in the Catalogue depends upon at least two observations; and for nearly all stars brighter than 8·0 mag. the number is three or more. Many stars fainter than 9·0 mag., which could readily be observed on account of proximity to a programme star, were included in the work. Various subsidiary investigations are given by Professor Boss, such as comparisons with other catalogues, determinations of proper motions, &c., which serve to make the Catalogue a very complete one. The total number of stars whose places are given in this Catalogue is 8241.

As applying generally to the above Catalogues, it may be remarked that no proper motions have been applied to the stars' places as printed (with the exception of stars of the "Fundamental Catalogue"), but values of the proper motions of many of the stars, some of which have been investigated during the progress of the work, are given in the notes. In addition to the mean places, the Catalogues give the precession and secular variation for each star, the mean epoch of observation, the zones in which the observations are to be found, and the reference to the *Durchmusterung*. These Catalogues are of peculiar importance at the present time on account of their applicability to the work of the International Photographic Survey of the heavens. Those parts containing the zones under-

taken at Kasan (+80° to +75°), Cambridge, U.S. (+55° to +50°), Lund (+40° to +35°), and Leiden (+35° to +30°) may, we believe, be expected to be published in the near future. It is to be hoped that the others will follow without unreasonable delay.

The Munich Catalogue of 33,082 *Stars for the Epoch* 1880.

The various zone catalogues of stars observed at the Munich Observatory during the years 1840–1872, reduced to the epoch 1850·0, and published in the *Supplementbände* to the *Munich Annalen*, were considered by Lamont, under whose direction the observations and reductions were made, as provisional only. Lamont projected the formation of a general catalogue, giving the positions of over 33,000 stars for the epoch 1880·0, deduced from some 75,000 observations, resulting from a discussion of the star-places given in the various zone catalogues. This extensive work, however, Lamont did not live to accomplish, and it has now been completed and published by Professor Seeliger, Lamont's successor in the directorate of the Munich Observatory. The catalogue forms Band I. of the *Neue Annalen der K. Sternwarte in Bogenhausen bei München.*

The observations were made with the Reichenbach Meridian Circle of the Observatory, the telescope of which has an object-glass, with aperture of 109 mm., and the circle a diameter of 0·95 m. During the earlier years of observation the transits were observed by the eye-and-ear method, and the circle was read by four verniers; afterwards a chronograph was used, and the circle read by two microscopes. An auxiliary arc was also supplied for reading off small differences of declination for the zone observations. A magnifying power of 110 was used throughout.

For the formation of the general catalogue the various zones have been compared together where they overlap, each, as far as possible, being reduced to the mean of all the rest; and in this way, by successive approximations, the stars in the different zones have been reduced to a homogeneous system. The positions thus formed for 1850·0 have been brought up to 1880·0 by means of Bessel's value of the precession. The places of the standard stars used in the reductions were taken from the ephemerides, published in the *Berliner Jahrbuch*, for the different years of observation.

The general catalogue thus formed gives the places of 33,082 telescopic stars, down to the 10th mag. inclusive, situated between −32° and +24° declination. Unfortunately, the stars are very unequally distributed—a circumstance which, for some purposes, detracts much from the value of the catalogue. Thus in R.A. 3^h-4^h, there are only 197 stars, whilst in R.A. 19^h-20^h there are 8498 stars; these being the extreme cases. Professor

Seeliger has carefully compared the star-places of the Munich Catalogue with those of various other catalogues, and with very satisfactory results. The agreement with the Fundamental Catalogue of the *Astronomische Gesellschaft* is remarkable, and shows that the places of these fainter stars, many of which are not to be found in hitherto published star catalogues, may be used with confidence. Professor Seeliger's work will doubtless prove one of great utility to practical astronomers, especially in the determination of the proper motions of faint stars.

The Second Melbourne General Catalogue of 1211 *Stars for the Epoch* 1880.

This Catalogue contains the results of observations made with the old transit circle of 5 inches aperture from the beginning of 1871 to the end of August 1884. The separate results of the observations from which the Catalogue has been compiled have been published in vols. v., vi., and vii. of the *Melbourne Observations*. The great majority of the right ascensions and polar distances of the Catalogue have been corrected for the effect of proper motion; and the polar distances further corrected so as to depend on the colatitude and system of refraction corrections (differing to the north and to the south of the zenith) previously adopted in the formation of the First Melbourne General Catalogue.

The adopted proper motions have been taken from the Catalogues of Auwers, Stone, Newcomb, and Gould; and when not obtainable from these sources have been specially computed—generally from a comparison of the Cape observations, 1829 to 1852, with recent Melbourne places. "Most of these proper motions must be considered as only provisional." They have, however, been used in forming the adopted star places.

In addition to the annual precession, the Catalogue gives the "second term of the precession" (or half the secular variation), and also the "third term of the precession" for each star, as well as the logarithms of the Besselian star numbers in Baily's order. There is also given in the Introduction a table to facilitate the computation of precessions by the rigorous trigonometrical formulæ, for use in the case of stars not far from the pole. It will thus be seen that the Catalogue is a very complete one, and reflects great credit on Mr. E. J. White, the First Assistant at the Melbourne Observatory, by whom it has been reduced and prepared for publication. The stars whose places are given in the Catalogue appear to be of quite a miscellaneous character; a large proportion of them are observable in these latitudes, and will therefore be available for comparison with observations obtained at stations where they culminate at widely different altitudes.

The Leiden Zone Observations.

The fifth volume of the *Annalen der Sternwarte in Leiden*, recently published, contains the remainder of the observations of the stars in the zone 30°—35° north declination (the portion of the programme of the *Astronomische Gesellschaft* undertaken at Leiden), the first instalment of which appeared in Band iv. of the same series. The number of observations contained in Band v. is 9954, and in Band iv. 10,395, making a total of 20,349. The number of stars in the working list, occurring within the above-mentioned limits of declination, is 10,250; there therefore remain but 151 observations to complete an average of two observations for each star. There are, besides, some cases in which a third observation is desirable on account of discordance in the results already obtained. These supplementary observations will appear in a subsequent volume.

Professor Pickering's Photometric Revision of the Durchmusterung.

The Harvard College Observatory has recently published a further important contribution to the Photometry of the Heavens. Vol. xxiv. of the *Annals* is devoted to results of observations made with the meridian photometer during the years 1882–88.

The present series differs from that known by the name of the *Harvard Photometry* (which was noticed in a previous report), inasmuch as the aperture of the telescopes employed was four inches instead of two, and stars of the ninth magnitude were thus rendered as easy to observe as those of the sixth magnitude with the former instrument.

It will be remembered that the meridian photometer is an instrument provided with two object-glasses, mounted side by side in a fixed position, upon which the light of two stars near the meridian is thrown by means of reflecting prisms or mirrors, while the images thus formed are photometrically compared by polarising apparatus. As they are produced by similar means and viewed upon the same background, the comparison is apparently free from systematic error. The larger instrument was constructed in the year 1882; the two four-inch object-glasses had focal lengths of 57 and 65 inches respectively. The field was 40′ in diameter, and the magnifying power employed was 28.

In the *Harvard Photometry* the brighter stars were compared solely with *Polaris*. In the present observations λ *Ursæ Minoris* was selected as the standard star, but in order to avoid any error which might result from a possible variation in its bright-

ness, the results are made to depend upon a series of 100 circumpolar stars, the magnitudes of which were frequently determined with the smaller instrument.

The principal work undertaken with the new instrument, the results of which are now published, was the determination of the magnitudes of a sufficient number of stars in the *Durchmusterung* and distributed with approximate uniformity, to serve as standards of reference for future estimates or measures of magnitude. In the revision of the *Durchmusterung* undertaken by various observatories under the auspices of the *Astronomische Gesellschaft*, each zone extends 10′ north and 10′ south of the limiting declinations. Each star in a narrow zone of 20′ would be observed at least twice at each of two observatories. Consequently there would be four independent estimates of magnitude available for comparison.

It was this fact that determined Professor Pickering to photometrically measure all stars not fainter than magnitude 9·0, in zones of 20′ in width, having their middle parallels at the declinations 0°, +5°, +10°, +15°, &c., to +85°, and, in addition, similar zones at −5°, −10° to −20° were observed.

The volume under consideration contains some miscellaneous measurements in addition to the catalogue of the magnitudes of stars observed in the photometric revision of the *Durchmusterung*.

Some estimate may be formed of this extensive work when we learn that "the total number of series of measurements is 1067, and the number of separate objects observed is 20,982. Four photometric settings were made upon each object, and these were repeated on the average between three and four times. The total number of settings is 267,092." When it is still further borne in mind that about two-thirds of these measures were made by Professor Pickering himself, it is possible to gauge the admirable, unrelaxing energy and skill that characterises the present Director of the Harvard College Observatory.

In the Catalogue the stars are, of course, arranged in zones, giving the *Durchmusterung* number—approximate R.A. and Decl. for 1855—the Bonn estimations of magnitude compared with the present photometric measures—the numbers of the series of observations in which the stars occur. The remaining columns give the residuals corresponding to the separate series, expressed in the same notation as was adopted in the *Harvard Photometry*, and the residuals similarly expressed corresponding to certain estimates of magnitude made concurrently with the measures.

Of the miscellaneous photometric measurements, there is given a catalogue of 3180 *Durchmusterung* stars not included in the above zones. These stars are arranged in order of right ascension for the epoch 1900. The columns give similar details to those in the zone catalogue. Professor Pickering designates the photometric magnitudes of this Catalogue by the letters M.P. (presumably "Meridian Photometry"), in contradistinc-

tion to H.P. ("Harvard Photometry"), employed in the catalogue published in vol. xiv. of the *Annals*.

Measurements were made of 166 variable stars, and the results are given in a separate section of that work. Finally there is given a series of measurements of *Jupiter's* satellites, *Iapetus*, *Uranus*, *Neptune*, and four minor planets, *Ceres*, *Pallas*, *Juno*, and *Iris*.

The volume is a display of an extraordinary amount of work carried out apparently with such high excellence and indefatigable zeal as cannot fail to add further renown to the Astronomical Establishment of Harvard College.

Dr. Dunér's Determination of the Rotation Period of the Sun.

During the preparation of his great Atlas of the Solar Spectrum M. Thollon drew attention to the advantages offered by a comparison of solar lines with the telluric lines in their immediate neighbourhood, for the determination of the velocity of the Sun's rotation. The Sun's rotation is, comparatively speaking, so slow that the displacement of the lines in the spectra of the E and W limbs, owing to the approach of the one and the recession of the other, is but small in amount, and when it is sought to compare the spectra of the two limbs together directly, various minute errors assume a grave importance, those arising from an unequal heating of the jaws of the slit being particularly troublesome. When, however, suitably chosen telluric lines are adopted as the reference lines, these sources of error are eliminated, and the measures become more accordant and trustworthy. Dr. Dunér has recently (*Ast. Nach.* No. 2968) published the results of three years' work, in which the speed of the Sun's rotation has been determined by this method, and not merely for the Equator, but for different latitudes up to 75°. The result he deduces shows a close correspondence with the deductions of Carrington and Spoerer from their observations of Sun-spots, with this advantage in favour of the spectroscopic method, that it can be applied to any latitude, whereas Sun-spots are rare above 35°, and practically cease at 40°. A period of $25^{d}\cdot46$ is deduced for the sidereal rotation at the Equator, and $38^{d}\cdot54$ for that at lat. 74°·8; but it must be remembered that a very minute difference in the measures would make a very considerable difference in the rotation period deduced, and especially so for high latitudes. Dr. Dunér gives 0·002 tenthmetres as the probable error of the results of a season; this would correspond to $0^{d}\cdot7$ at the Equator, and to more than 11 days at 75°. So that, though the measures distinctly point to a diminution of angular velocity with increased distance from the Equator, the amount of that diminution, especially in the higher latitudes, is still left open to considerable uncertainty.

The measures were made with a diffraction spectroscope furnished with a Rowland grating, and the lines observed were the solar lines, λ 6301·72 and λ 6302·72, due to iron, and the telluric lines, λ 6302·21 and λ 6302·97, due to oxygen. It would be a work of considerable interest to apply the same method to other regions of the solar spectrum; the group at λ 5975, to which M. Thollon drew attention in the *Comptes Rendus*, vol. xci. p. 368, offering some special advantages.

E. W. M.

M. Thollon's Atlas of the Solar Spectrum.

The principal feature of the third volume of the *Annales* of the Nice Observatory is the magnificent Atlas of the Solar Spectrum designed by the late M. Thollon, whose untimely death lends an especial and melancholy interest to this his last and greatest undertaking. Fortunately, although he was not able to delineate the entire spectrum, he lived long enough practically to complete his charts for the part he had commenced upon, and this part is, for the special object he had in view, the most important.

The Atlas as it stands is divided into 33 maps, each about a foot in length, and represents the spectrum from A to *b*. The scale, therefore, is a most ample one, one-tenth mètre at D being represented by five millimètres on the chart, and, the spectrum being prismatic and not normal, one at *b* by nine millimètres. About 3200 lines are shown, of which 2090 are purely solar, 866 purely telluric, and 246 would appear to be due to telluric lines superposed upon solar lines. But in spite of the ample scale of the map, and the extreme care bestowed upon its construction, it could scarcely have attained the standard of character its author hoped for were it not for a further excellence it possesses; for the advance of photography has rendered it possible to supply a map of the entire spectrum with an ease, an accuracy, and a fulness of detail which direct micrometric observation cannot hope to rival. It was M. Thollon's desire, however, not to represent the spectrum under one single aspect alone, but practically under every variety of solar elevation, and of aqueous absorption. This he has secured by a fourfold representation: the first showing the spectrum as obtained from a low Sun, 10° altitude, and the air fairly dry; the second and third with a Sun at 30° altitude, the air in one case being at the point of saturation, and in the other very dry; and lastly the purely solar lines are shown by themselves, so that the spectrum is delineated as it would be seen from a station situated above our atmosphere. To secure this fourfold representation must have entailed an enormous increase in the time and labour

expended on the chart, but the gain to those who will use it will be fully in proportion, and the debt which spectroscopists owe to M. Thollon's memory will long remain a heavy one. But for this feature the Atlas—especially since, as stated above, it is not a normal one—would have been practically superseded before it was published; with it it will, in all probability, long remain a standard work of the highest value.

The engraving of the charts, the execution of which is of the utmost beauty, has been entrusted to M. Legros. E. W. M.

The Photographic Chart of the Heavens.

During the past year considerable progress has been made in completing preparations and making preliminary trials with the astro-photographic telescopes. The majority of the observatories participating in the work have their instruments practically ready; and it is to be hoped that at the approaching meeting of the Permanent Committee in March next decision will be arrived at with regard to some of the outstanding questions, so that little further delay need elapse before actually commencing the work.

The fifth number of the *Bulletin du Comité International Permanent pour l'exécution Photographique de la Carte du Ciel* has recently appeared. It contains three papers on the photographic magnitudes of stars by Professor Holden and Mr. Schaeberle; an abstract of M. Lindemann's photometric determination of the star magnitudes of the Bonn Durchmusterung, from the Supplement to the Pulkowa observations; a paper by M. Trépied on the necessity of coming to some understanding as to what is meant by stars of the 9th, 11th, and 14th magnitudes on the photographic plates; and two important papers by the Astronomer Royal.

The Report last year announced the distribution of the zones among the several observatories, as assigned by the Permanent Committee in September 1889. The principle upon which that allotment was made was to assign a zone as near as possible to the zenith of the observatory, so as to minimise the effects of refraction. Mr. Christie points out that at such altitudes the dew-caps of the telescopes would be of little use, and the object-glasses would become dewed. He, therefore, proposes that, save in one or two exceptional cases, no observatory shall photograph a zone at a less zenith distance than about 12°. In a second paper, Mr. Christie deals with the resolutions of the Congress as to the two series of plates, the corner of a plate in one series falling on the centre of a plate in the second series, and he proposes to reduce the number of plates in a zone as we proceed from the Equator to the Poles. In a table, which is subjoined, he gives his proposed disposition of the zones, and the number of plates necessary to be taken by each observatory.

Observatory.	Latitude.	Declination of Zone.	Number of Plates.
Greenwich	+51° 29′	+90° to +65°	1149
Rome	+41 54	+64 „ +55	1040
Catania	+37 30	+54 „ +47	1008
Helsingfors	+60 9	+46 „ +40	1008
Potsdam	+52 23	+39 „ +32	1232
Oxford	+51 46	+31 „ +25	1180
Paris	+48 50	+24 „ +18	1260
Bordeaux	+44 50	+17 „ +11	1260
Toulouse	+43 37	+10 „ + 5	1080
Algiers	+36 48	+ 4 „ − 2	1260
San Fernando	+36 28	− 3 „ − 9	1260
Tacubaya	+19 24	−10 „ −16	1260
Santiago	−33 27	−17 „ −23	1260
La Plata	−34 55	−24 „ −31	1360
Rio	−22 54	−32 „ −40	1376
Cape	−33 56	−41 „ −51	1512
Sydney	−33 52	−52 „ −64	1400
Melbourne	−37 50	−65 „ −90	1149

The Astronomical Society of the Pacific.

The great activity in observational astronomy that has of late years been witnessed in the United States has met with its natural result in the establishment, for the benefit of one portion of that wide area, of a society for the advancement and encouragement of the science of astronomy.

The occasion of the solar eclipse of 1889 January 1, brought together many amateur and professional astronomers resident in California, the outcome of which was the founding, a month afterwards, at San Francisco, of the "Astronomical Society of the Pacific." This society was formed under the auspices of the Lick Observatory, and started into existence with all the advantages derivable from proximity to such a finely established institution, controlled by a staff of highly competent astronomers.

Two volumes of publications have already appeared, containing many valuable communications. Among the more interesting papers published in the first volume will be found one on the Helical Nebulæ, by Professor Holden; an important investigation of the Photographic Brightness of the Fixed Stars, by Mr. Shaeberle; and a series of observations of *Jupiter* during the years 1879–1886, by Mr. Barnard. The second volume contains numerous original papers, among which is one of conspicuous

merit by Mr. Keeler, "On the Motions of the Planetary Nebulæ in the Line of Sight."

Though the majority of the communications emanate from Professor Holden and his colleagues at the Lick Observatory, their general high character clearly indicates that the society is pursuing its object in a manner thoroughly worthy of the intentions of its promoters, and so as to form a useful centre for astronomical science in California.

Professor Bakhuyzen's Method for the Determination of Absolute Personal Equation.

Professor Bakhuyzen's description of a personal equation apparatus, and the results obtained by it, is dedicated to the Pulkowa Observatory by the Leiden Observatory, on the occasion of the fifty-year Jubilee 1889 August 19. The zone (80°–90°, Dec. N.) observations undertaken at Leiden being then almost finished, Herr Bakhuyzen thought it would add to their value could he obtain absolute personal equations for the observers. The apparatus devised for this purpose consists first of a fixed lens 82 mm. aperture, which receives light from an artificial star; close to it, and adjusted so that the light from the lens falls on it at an angle of 46° 27′, is a prism whose refracting angle is 13′ 33″. This prism is capable of motion round a horizontal axis in order that its refracting edge may easily be placed vertical. The light next falls on a prism, with a refracting angle of 15′ 51″·5, held in a metal ring, and movable about a vertical axis. A long arm fixed to this ring is moved in a horizontal plane, and as it so moves it rotates the prism, and also passes over three platinum contacts, completing a galvanic circuit at each, and so registering a signal on a chronograph. These contacts can be so adjusted that the signal is registered at the instant the artificial star is bisected by one of the threads in the reticule of the transit-circle. The arm and, consequently, the prism move by clock-work. The length of the arm is 510 mm., and the duration of contact $0^s{\cdot}06$. The principal point, however, is in the great care with which the adjustments were made. To see that the beginning of contact coincided with the bisection by the transit-circle thread, a telephone was adjusted so that the observer could hear the contact and make his bisection. Again, to avoid as much as possible any systematic error, the assistant at the machine also judged of the contact, and bisection was not finally made until both were satisfied. This adjustment was made before and after the observations. It was then questionable whether the registration on the chronograph was coincident with the contact or was retarded. To decide this a microphone was placed at the chronograph and connected with a second telephone, so that by placing one at

each ear the observer could hear both the contact and the strike of the armature. No difference was detected. However, for greater security the bisection was made first by hearing the contact, and then by hearing the strike of the armature. With the aid of mirrors the observations could be made also by reflexion. The observations themselves are given, and the results tabulated. These results agree very favourably with the differential results obtained by the ordinary star observations, and Professor Bakhuyzen thinks they may be applied with some degree of confidence. T. L.

Variation of Latitude.

In the years 1884–1885 Dr. F. Küstner, of the Berlin Observatory, in making some observations by Talcott's method for the determination of the constant of aberration, found a puzzling systematic error, which he could not regard as instrumental, and which he characterised as a change in the latitude of Berlin by a considerable fraction of a second of arc. The possibility of changes in the latitude, either periodic or irregular, had been discussed at the meeting of the "Association Géodésique Internationale" at Rome in 1883, when a committee was appointed to consider the question; but Dr. Küstner was the first to publish definite observations claiming to show such a change, if we except inequalities of annual period in observations of N.P.D., which have long been recognised at some of the older observatories, but which have generally been ascribed to meteorological causes.

A further exception might perhaps be made in the case of Greenwich, the latitude of which was supposed some years ago to be undergoing a secular change, but the present Astronomer Royal showed good cause for believing this change to be fictitious (Mem. R.A.S., vol. xlv.).

It is quite possible that the origin of the apparent change at Berlin in 1884–1885, and of those to which we shall presently refer, is meteorological; and this was the view to which Dr. Foerster inclined in bringing the matter before the Association Géodésique in 1888. But the subject was in any case worth serious attention; and it was determined, as a first experiment, to make similar and contemporaneous observations by Talcott's method at Berlin, Potsdam, Prague, and Strasburg, from the commencement of 1889. A comparison of the results obtained at the first three stations shows strikingly sympathetic apparent changes in the latitude, amounting to 0″·5 from crest to trough of a well-defined wave; and it follows that whatever be the cause of these fluctuations, it is one operative over a considerable area. This view is confirmed by an examination of observations at Pulkowa in 1884–1885, which are found to be

affected in the same manner as Dr. Küstner's. If, then, the motion is in the Earth's crust, we must suppose that at least the whole of Europe moves together, though it would be premature to say that the whole globe is affected; and, indeed, as remarked above, the phenomenon may still be meteorological. The next step will be to compare observations in nearly the same latitude and widely different longitudes, as was suggested by M. Fergola in 1883. He gave the following table of pairs of observatories eminently suitable for the purpose:—

	Difference of Latitude.	Longitude.
	° ′ ″	h m
Cape of Good Hope—Sydney	4 22	8 51
Santiago—Windsor (N.S.W.)	9 47	9 14
Rome—Chicago	3 53	6 40
Naples—New York (Columbia College) ...	6 22	5 53
Lisbon—Washington	11 7	4 31

It is to be hoped that it may be found possible to arrange operations in concert by at least one of these pairs, for the careful carrying out of a very limited programme would go far to settle the important question whether it be that the Earth's axis of rotation and axis of inertia are not sensibly coincident, or that there are changes in the disposition of atmospheric strata sufficient to account for the above facts. It is quite possible that a re-examination of existing material may be sufficient to enable us to choose between the two; but until this choice is made it seems unprofitable to speculate further as to the ultimate meaning of the first alternative. H. H. T.

Papers read before the Society from February 1890 to January 1891.

1890.

Mar. 14. On some celestial photographs taken with a large portrait lens at the Lick Observatory. E. E. Barnard.

γ *Coronæ Australis*. E. B. Powell.

On the proper motion of Groombridge 1830. W. T. Lynn.

Observations of the variable star S (10) *Sagittæ*. J. E. Gore.

A new class of binary stars. Professor E. C. Pickering.

Observations of Comet 1888 (Barnard, September 2), made at the Sydney Observatory with the 11½-inch equatoreal and filar micrometer. Communicated by H. C. Russell.

On a method of obtaining the error of a chronometer by equal altitudes of two stars on opposite sides of the meridian. Commander A. M. Field.

A simple method of obtaining an approximate solution of Kepler's equation. A. A. Rambaut.

On the parallax of double stars. A. A. Rambaut.

Observations of phenomena of *Jupiter's* satellites at Windsor, New South Wales, in the year 1889. John Tebbutt.

Photograph of the clusters 33 and 34 H VI. *Persei*. Isaac Roberts.

Suspected variability during short periods in certain stars in *Orion*. Isaac Roberts.

Further note, with a correction, on the spectrum of the Sun-spot of June 1889. Rev. A. L. Cortie.

Some experiments relating to the method of obtaining the coefficient of absorption of the wedge photometer. E. J. Spitta.

Ephemeris for physical observations of *Jupiter*, 1890. A. Marth.

Observations of the Moon made at the Radcliffe Observatory, Oxford, during the year 1889, and a com-

parison of the results with the tabular places from Hansen's Lunar Tables. E. J. Stone.

April 11. Fifth Catalogue of micrometrical measures of double stars made at the Temple Observatory, Rugby. G. M. Seabroke, A. P. Smith, and H. P. Highton.

Discovery of Comet Brooks, 1890. W. R. Brooks.

Photograph of stars in the region of Tycho's *Nova*. Isaac Roberts.

A mechanical theory of the solar corona. J. M. Schaeberle.

On the Nautical Almanac. Lieut.-Gen. J. F. Tennant.

Note on the apparent star places of the Nautical Almanac. H. H. Turner.

Note on the Sun-spots of 1889. E. W. Maunder.

May 9. On the proper motion of three stars. W. T. Lynn.

Observations of the planets *Victoria* and *Sappho*, made with the Cambridge transit-circle in the year 1889. Communicated by Professor J. C. Adams.

The apparent projection of stars upon the bright limb of the Moon at occultation, and similar phenomena. George Davidson.

On the orbit of δ *Cygni*. J. E. Gore.

Totality of the eclipse of 1889 December 22. Professor D. P. Todd.

Comparison of the right ascensions of clock stars in the Greenwich Ten-Year Catalogue for 1880 with the Fundamental Catalogues of the American Ephemeris and the Astronomische Gesellschaft. Professor S. Newcomb.

A revolving diagonal, with combined total reflection and solar prism. W. Schooling.

Mean areas and heliographic latitudes of Sun-spots in the year 1889, deduced from photographs taken at Greenwich, at Dehra Dûn (India), and in Mauritius. Communicated by the Astronomer Royal.

Observations of Comet *a* 1890 (Brooks), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Notes on reflecting telescopes, and on the making of large discs of glass for them. A. A. Common.

Observations of *Mimas*, 1890. A. A. Common.

Ephemeris for physical observations of the Moon, 1890 July 1 to December 31. A. Marth.

The Jovian evection. E. Nevill.

June 13. The star-places of the Second Melbourne General Catalogue for 1880. A. M. W. Downing.

On star-correction tables. W. H. Finlay.

On the variable star U ("Nova") *Orionis*. J. E. Gore.

On a coming conjunction of a remarkable dark spot

on *Jupiter* with the red spot, and the relative altitude of these objects. A. Stanley Williams.

Comparison of the Greenwich Ten-Year Catalogue with the Williamstown right ascensions of polar stars for 1885. Professor T. H. Safford.

Corrections to the elements of the orbit of *Juno*. A. M. W. Downing.

On the verification of the constants employed in the Uranometria Nova Oxoniensis. Professor C. Pritchard.

On the computation of the equation of the centre in elliptical orbits of moderate eccentricities. A. Marth.

A simple solution of Kepler's problem. A. Marth.

Observations of Comet *a* 1890 (Brooks), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Note on some variable stars near the cluster 5 M. A. A. Common.

Note on the scaling of Dr. Spitta's wedge by means of photography. Captain W. de W. Abney.

Nov. 14. On the real and apparent variations of the latitude of Greenwich. Professor F. Folie.

On an electrical control for driving clocks. H. C. Russell.

On the correction of micrometric measures for refraction. H. Jacoby.

On a possible cause for lunar libration other than an ellipsoidal figure. S. E. Peal.

Observations of Comet *a* 1890 (Brooks), made at the Royal Observatory, Greenwich. Communicaed by the Astronomer Royal.

The red spot on *Jupiter*. J. E. Keeler.

Two auxiliary tables for the solution of Kepler's problem. A. Marth.

Ephemerides of the satellites of *Saturn*, 1890-91. A. Marth.

Ephemeris of the satellite of *Neptune*, 1890-91. A. Marth.

Spectroscopic notes and queries. Rev. A. L. Cortie.

Observations of the spectra of Sun-spots in the region B–D, made at the Stonyhurst College Observatory in the years 1882–89. Rev. A. L. Cortie.

On the orbit of 99 *Herculis*=Alvan Clark 15. J. E. Gore.

Note on stationary or long-enduring meteor-radiants. W. H. S. Monck.

On some celestial photographs recently taken at Sydney Observatory (with appendix). H. C. Russell.

Observations of the variable star R *Carinæ*, from November 1886 to June 1890. John Tebutt.

Observations of comets made at the Orwell Park Observatory in the years 1889–90. J. I. Plummer.

Preliminary note on the duplicity of *α Lyræ*. A. Fowler.

On the variation of the spectra of R *Coronæ* and R *Scuti*, and on the spectrum of R *Aurigæ* and R *Andromedæ*. Rev. T. E. Espin.

Some experiments relating to the photometric comparison of points of light with objects of sensible area. E. J. Spitta.

Note on the spot-groups of 1888. E. W. Maunder.

On a mechanical method of describing a parabolic curve. R. Inwards.

Comparative photographs of the high Sun and low Sun visible spectra, with notes on the means of photographing the red end of the spectrum. F. McClean.

Photograph of the A line in the solar spectrum. G. Higgs.

Note on the spot-group of 1890 August 25–September 5. E. W. Maunder.

Observations of the solar eclipse of 1890 June 16–17, made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Dec. 12. Note on some celestial photographs taken at the Sydney Observatory. H. C. Russell.

New nebulæ. W. F. Denning.

Note on Hind's variable nebula in *Taurus*. S. W. Burnham.

Ephemerides of the satellites of *Saturn*, 1890–91 (concluded). A. Marth.

Elements and ephemeris of Zona's comet. J. R. Hind.

1891.

Jan. 9. Observations of the planets *Victoria* and *Sappho* made with the meridian-circle at Dunsink. A. A. Rambaut.

Remarks on Mr. Fowler's paper on the duplicity of *α Lyræ*. Professor H. C. Vogel.

The proper motion of H 1968. S. W. Burnham.

Photographic evidence of variability in the nucleus of the great nebula in *Andromeda*. Isaac Roberts.

Mr. Roberts's new Observatory on Crowborough Hill, Sussex. Isaac Roberts.

A theory of the cause of gravitation founded upon the dynamical theory of heat. J. G. Vine.

A list of published lunar sketches and photographs, arranged according to the Sun's position. A. Marth.

Spectroscopic results for the motions of stars in the

line of sight, obtained at the Royal Observatory, Greenwich, in the year 1890. No. XIV. Communicated by the Astronomer Royal.

Note on the recent determination of the longitude of Paris. H. H. Turner.

A comparison between the Greenwich lunar observations, 1887, and Hansen's Tables, uncorrected and corrected, for the change in the unit of mean time introduced in the year 1864, and with Hansen's Tables as modified by Professor Newcomb and Mr. Stone. E. J. Stone.

List of Public Institutions and of Persons who have Contributed to the Library &c. since the last Anniversary.

Her Majesty's Government in Australia.
Her Majesty's Government in India.
The Lords Commissioners of the Admiralty.
The Italian Government.
The Norwegian Government.
British Association for the Advancement of Science.
British Astronomical Association.
British Horological Institute.
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Liverpool Literary and Philosophical Society.

Liverpool Observatory.
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Stonyhurst College Observatory.
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Berlin, Physical Society.
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Berne University.
Bombay Branch of the Royal Asiatic Society.
Bordeaux Observatory.
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Boston, American Academy of Arts and Sciences.
Brisbane, Queensland Branch of the Royal Geographical Society of Australasia.
Brussels, Royal Observatory.
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Buenos Ayres, Argentine Meteorological Office.
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Göttingen, Royal Society of Sciences.
Haarlem, Teyler Museum.
Halle, Leopold-Caroline Academy of Naturalists.
Harvard College Astronomical Observatory.
Helsingfors, Geographical Society of Finland.
Helsingfors, Society of Sciences of Finland.
Hong Kong Observatory.
International Geodetic Association.
Italian Meteorological Society.
Italian Society of Sciences.
Japan, Seismological Society.
Kiel, Royal Observatory.
Leghorn, Technical and Nautical Institute.
Leipzig, Astronomical Society.
Leipzig, Royal Saxon Society of Sciences.

Leyden Observatory.
Lick Observatory of the University of California.
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Manilla Meteorological Observatory.
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Mexico, Society "Antonio Alzate."
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Paris, Polytechnic School.
Philadelphia, American Philosophical Society.
Philadelphia, Franklin Institute.
Prague, Imperial Observatory.
Pulkowa Observatory.
Rio de Janeiro Observatory.
Rome, Italian Spectroscopic Society.
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Rome, Royal Academy *dei Lincei*.
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Prof. W. C. Winlock.
Dr. R. Wolf.
Herr A. Wolfer.
Prof. C. V. Zenger.

The meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected:—

President.

Lieut.-Gen. J. F. TENNANT, C.I.E., R.E., F.R.S.

Vice-Presidents.

Capt. W. DE W. ABNEY, C.B., R.E., D.C.L., F.R.S.
J. C. ADAMS, Esq., M.A., Sc.D., LL.D., D.C.L., F.R.S., Lowndean Professor of Astronomy, Cambridge.
J. W. L. GLAISHER, Esq., M.A., Sc.D., F.R.S.
E. J. STONE, Esq., M.A., F.R.S., Radcliffe Observer.

Treasurer.

A. A. COMMON, Esq., F.R.S.

Secretaries.

A. M. W. DOWNING, Esq., M.A.
E. B. KNOBEL, Esq.

Foreign Secretary.

WILLIAM HUGGINS, Esq., LL.D., D.C.L., F.R.S.

Council.

Sir R. S. BALL, LL.D., F.R.S., Andrews Professor of Astronomy in the University of Dublin, and Royal Astronomer of Ireland.
ARTHUR CAYLEY, Esq., M.A., Sc.D., LL.D., D.C.L., F.R.S., Sadlerian Professor of Pure Mathematics, Cambridge.
W. H. M. CHRISTIE, Esq., M.A., F.R.S., Astronomer Royal.
Hon. Sir JAMES COCKLE, M.A., F.R.S.
GEORGE KNOTT, Esq., B.A., LL.B.
FRANK MCCLEAN, Esq., M.A.
E. W. MAUNDER, Esq.
Capt. WILLIAM NOBLE.
W. E. PLUMMER, Esq., M.A.
ISAAC ROBERTS, Esq., F.R.S.
E. J. SPITTA, Esq.
H. H. TURNER, Esq., M.A., B.Sc.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LI. MARCH 13, 1891. No. 5

Lieut.-General J. F. TENNANT, R.E., C.I.E., F.R.S., President, in the Chair.

Thomas Richard Clapham, Austwick Hall, Clapham, Lancaster; and
Arthur Kennedy, 1 Clement's Inn, W.C.; and Ashtead, near Epsom, Surrey,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Alfred Henry Fison, D.Sc., Assistant Professor of Physics, University College, London (proposed by F. W. Levander);
Thomas Gordon, F.R.Met.Soc., Ironmonger, 9 Scotch Street, Whitehaven (proposed by Sir R. S. Ball);
George E. Hale, B.Sc., 4545 Drexel Boulevard, Chicago, U.S.A. (proposed by S. W. Burnham).

One hundred and nine presents were announced as having been received since the last meeting, including among others:—

S. Newcomb, Discussion of Observations of the Transits of *Venus*, 1761 and 1769, and G. W. Hill, New Theory of *Jupiter* and *Saturn*, presented by the American *Nautical Almanac* Office; Catalog der Astronomischen Gesellschaft, zone +65° bis +70° (Christiania), presented by the Society; E. Weiss, Katalog der Argelander'schen Zonen, −15° bis −31°, presented by Professor

Weiss; J. E. Gore, Catalogue of Binary Stars for which Orbits have been Computed, presented by the Author; Madras Observatory, Meridian Observations made in the years 1868–70, presented by the Observatory; W. T. Lynn, Celestial Motions, 7th edition, presented by the Author; Royal Observatory, Edinburgh, Catalogue of the Crawford Library, presented by the Observatory; L. Becker, The Solar Spectrum at Medium and Low Altitudes, presented by the Author; O. Callandreau, Étude sur la théorie des Comètes périodiques, presented by the Author; R. Wolf, Handbuch der Astronomie, Band I., Theil II., presented by the Author; 17 original negatives of *Jupiter*, made with the 36-inch Equatoreal of the Lick Observatory, presented by Professor Holden; Comparative Photographs of High and Low Sun Spectra, presented by Mr. F. McClean; Stand for Lantern at evening meetings, presented by Mr. W. Schooling; Oxygen bottle, presented by Mr. E. Ristori.

Notes on the Preparations for the Work of the Astrophotographic Chart at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

I. *The Catalogue of Guiding Stars.*

The resolutions of the Permanent Committee relating to guiding stars are as follows:—

11. On prendra comme étoile-guide une belle étoile du champ, dont la position soit connue à 5″ près.

12. Une Commission de cinq membres (MM. Bakhuyzen, Christie, Gill, Kapteyn, Lœwy) est nommée dans le but:

1. De déterminer les positions des centres de toutes les plaques pour l'équinoxe de 1900.

2. De choisir les étoiles-guides et d'assurer leur réduction.

The positions of the centres of the plates decided on by this Commission were published in the fifth number of the *Bulletin* in a paper by W. H. M. Christie. The centres are all at whole minutes of R.A. and whole degrees of declination for the equinox of 1900. The distances in R.A. between centres in the same zone vary from 8 minutes at the Equator to 3 hours at declination $+89°$; and the centres are so arranged that no star is more than 63′ from the centre of some plate.

As regards the second part of the resolution, the work of selecting guiding stars has been divided amongst the observa-

tories which expressed their willingness to undertake it as follows :—

Observatory.	Zone in Decl.	Observatory.	Zone in Decl.
Greenwich ...	+90° to +60°	Leiden	−6° to −9°
Pulkowa	+59 „ +37	Melbourne ...	−10 „ −14
Leiden	+36 „ +30	Cape of Good Hope	−15 „ −23
Greenwich ...	+29 „ +25	Groningen ...	−24 „ −40
Paris	+24 „ + 8	Cape of Good Hope	−41 „ −51
Algiers	+ 7 „ − 2	Sydney	−52 „ −64
Greenwich ...	− 3 „ − 5	Melbourne ...	−65 „ −90

Mr. Hollis has been engaged for some time on the zones allotted to Greenwich, and the work is well advanced.

Professor Bakhuyzen proposed the following rules for selecting these stars, suggested by his experience in a preliminary examination of certain portions of the sky :—

1. Generally the brightest star within a circle of 22′ radius from the centre of the plate was to be chosen.

2. If, however, this star was fainter than 9·0 mag., the nearest star to the centre of 9·0 mag. or brighter was to be added as a supplementary guiding star.

Mr. Hollis originally selected stars for the zones +60° to +80° according to these rules, but as he found rather a large proportion of faint stars, the effect of extending the radius of the circle to 30′ was examined. The numbers of stars of different magnitudes found in the two cases are compared in the following table :—

Number of Guiding Stars within limiting circle of

Magnitude.	22′ radius.	30′ radius.
9·5	90	28
9·1 − 9·4	155	64
8·6 − 9·0	291	211
8·1 − 8·5	295	242
7·6 − 8·0	178	242
7·1 − 7·5	126	212
6·6 − 7·0	129	191
6·1 − 6·5	58	92
5·6 − 6·0	43	63
5·1 − 5·5	14	24
Brighter than 5·1	13	23

The numbers of additional stars required in accordance with the second rule were 277 and 133 in the two cases respectively.

It is to be noted that the co-ordinates of the guiding stars relatively to the centre of the plate are to be measured in the plane of the plate, which is a tangent plane to the sphere, and that corrections will be required to the differences of R.A. and declination between the star and the centre of the plate to convert them into these rectangular co-ordinates in order that the centre of the plate may be set as accurately as practicable to the defined position.

II. *Errors of Réseau.*

The resolutions of the Permanent Committee relative to the réseau are as follows:—

6. Les traits des réseaux auront 130^{mm} de longueur, leur distance sera de 5^{mm}. Le nom de l'observatoire sera inscrit sur le réseau.

15. Le réseau sera impressionné sur chaque plaque par de la lumière parallèle, dans un châssis placé devant l'objectif photographique lui-même, au foyer duquel on aura placé une source de lumière.

16. On fera usage d'un réseau pour la construction de la Carte.

17. Le réseau, pour la Carte, sera le même que pour le Catalogue.

Two very beautiful silver-on-glass réseaux have been received from Dr. Vogel, the plates being 160^{mm} square, and lines of 130^{mm} in length being ruled with a fine point on the silver (so as to leave clear glass) at intervals of 5^{mm}. Arrangements have been made for impressing these on the plate strictly in accordance with resolution 15. A circular metal plate is fitted to the dew-cap of the photographic telescope by four screws. In the centre of the plate is an aperture 140^{mm} square, opposite which the réseau and plate are to be placed. They are brought into this position in a dark-slide, $8\frac{1}{2}$ inches square, the réseau being held in the dark-slide by four thin plates of silver ($\frac{1}{50}$ inch thick) placed at the corners, which separate the silver film by a very small distance from the sensitive surface of the plate to be impressed.

The corresponding ground edges of the réseau and of the plate bear against three agate planes placed similarly to those determining the position of the plate in the telescope when photographing stars—viz., two agates bearing on the ground edge of the réseau marked A (which is the standard edge for orientation) at 142^{mm} apart, and one bearing on the middle of the ground edge marked B.

At the focus of the object-glass is placed a small electric lamp of about 1⅓ candle-power (6 volts and 0·8 ampère) excited by a secondary battery of four small storage cells, all other light being of course excluded. With this arrangement, which gives a pencil of parallel rays for imprinting the réseau, it is found that an exposure of thirty seconds gives a good image of the réseau on the plate.

With some of the réseaux Dr. Vogel has supplied a table of their errors. This was not done for the Greenwich réseaux, and the errors have been examined at Greenwich. The investigation is not yet complete, but the following results have been obtained:—

(α) The lines are sensibly straight and parallel, or at least are parallel and sensibly similar curves. This seems to have been assumed by Dr. Vogel in the lists of errors he has issued, for he has only given one number applying to the whole line of 130^{mm} in length. At Greenwich the lines parallel to the side B on a photographic copy of one of the réseaux were compared at nearly every 5^{mm} of their length by means of a micrometer (constructed for measuring photographs of the Transit of *Venus*, 1874), with a glass millimetre scale. The distances between them were found to remain constant within the limits of accidental error. The consideration of $16 \times 27 = 432$ residuals shows the limits of possible error. These residuals are grouped as follows:—

	No. of Residuals.
Greater than 0″·50	0
0″·50 to 0·40	2
0·40 to 0·30	9
0·30 to 0·20	40
0·20 to 0·10	140
0·10 to 0·00	241

(β) The errors of the above lines from a uniform scale are very small, and have the following values, if the errors of the millimetre scale, carefully determined at the time the Transit of *Venus* photographs were being measured in 1877, are still valid.

Réseau line.	Error shown by Comparison with Scale.	Correction to Scale.	Error of Réseau.
	mm.	mm.	mm.
A 1	−0·0222	+0·0120	−0·0102
A 2	−0·0157	0·0121	−0·0036
A 3	−0·0061	0·0073	+0·0012
A 4	−0·0037	0·0096	+0·0059
A 5	−0·0035	0·0116	+0·0081
A 6	+0·0002	0·0105	+0·0107
A 7	+0·0006	0·0106	+0·0112
A 8	+0·0076	0·0047	+0·0123
A 9	+0·0051	0·0066	+0·0117
A 10	+0·0031	0·0082	+0·0113
A 11	−0·0002	0·0095	+0·0093
A 12	−0·0033	0·0146	+0·0113
A 13	+0·0002	0·0137	+0·0139
A 14	−0·0016	0·0114	+0·0098
A 15	+0·0035	0·0108	+0·0143
A 16	+0·0041	0·0108	+0·0149
A 17	+0·0035	0·0079	+0·0114
A 18	+0·0063	0·0101	+0·0164
A 19	+0·0088	0·0052	+0·0140
A 20	+0·0063	0·0093	+0·0156
A 21	−0·0110	0·0234	+0·0124
A 22	−0·0129	0·0268	+0·0139
A 23	−0·0090	0·0254	+0·0164
A 24	+0·0116	0·0031	+0·0147
A 25	+0·0110	0·0036	+0·0146
A 26	+0·0131	0·0041	+0·0172
A 27	+0·0031	0·0129	+0·0160

It is to be remarked that these errors are those of a copy, and the falling off at A 1 − 5 is possibly not the same on the original, but the effect of some photographic accident. The matter is still under investigation.

III. *Course of the Work, Weather, &c.*

It may be interesting to give a few notes of what has been accomplished since regular work was undertaken at the commencement of February. During the thirty-two days from February 9 to March 12, at least two observers have been on the alert from soon after sunset till midnight or later, on all days except three. Fifteen of these nights were completely cloudy; three were partially cloudy, as shown by a small number

of meridian observations; and eleven were available in some degree for photography, though several were more or less foggy. On these nights twenty-one plates have been exposed either for star-trails (for adjustment, &c.) or for regular photographs, representing a total duration of actual exposure of $12^h\ 49^m$. Better results will, doubtless, be obtained as the work becomes more familiar.

IV. *Star Photographs.*

In respect of the taking of actual photographs, attention must be paid to the following resolutions of the Permanent Committee :—

8. Chacun des directeurs d'observatoires aura la liberté de commander ses plaques à tel fabricant qu'il voudra choisir.

18. On adoptera, pour le temps de pose devant donner les étoiles de grandeur 11·0 le produit par 6·25 du temps de pose nécessaire pour obtenir la grandeur 9·0 de l'échelle d'Argelander.

19. Chaque observateur devra s'attacher à obtenir sur ses clichés destinés au Catalogue la grandeur 11·0, déterminée aussi exactement que possible au moyen de l'échelle d'Argelander que l'on prolongera au-delà de la grandeur 9·0 par l'emploi du coefficient 2·5.

A chacun sera laissé le soin d'apprécier si ses clichés contiennent les étoiles dont la grandeur atteint cette limite.

23. Il sera fait, pour chaque cliché du Catalogue, deux poses successives, la seconde ayant une durée d'un quart de celle de la première et de telle sorte que la distance des deux images soit de 2 à 3 dixièmes de millimètre.

Le Comité recommande aux observateurs de déplacer l'instrument *en déclinaison* pour effectuer la seconde pose, si leur instrument leur permet de la faire, c'est-à-dire s'il est muni d'un micromètre.

With respect to resolution 8 it may be stated that the following plates have been tried: Paget, Cramer, Seed, Star, Mawson and Swan. Our thanks are due to the various makers for the trouble they have taken in cutting plates to the required size and in grinding edges. The selection of the best plate for the work has been a matter of considerable difficulty where the merits are so nearly equal, but after some experience a slight preference is felt for the "Star" plates, if ferrous oxalate development be used.

The most important information with respect to resolution 19 has been derived from two plates taken on 1891 March 4 at $8^h\ 6^m$ +66° (one of the adopted centres in the region assigned to Greenwich), the first with an exposure of 30 min., and the second with two exposures of 6 min. and 1½ min. respectively. The northern halves of these two plates were carefully examined, and the diameters of the stars measured. All Argelander's stars in this region were clearly shown with the 1½ min. exposure with the exception of one, D.M. + 67°·519, which is

shown by the longer exposures to be photographically much fainter than D.M. + 67° ·520 close by. Further, the comparison of the diameters with Argelander's magnitudes gives the following approximate empirical formula connecting diameter in seconds of arc (d), magnitude (m), and time of exposure in minutes (t) :—

$$m = 13{\cdot}80 + 2{\cdot}5 \log t - 8{\cdot}3 \log d.$$

This is not advanced as a final result with full physical significance, but only as a convenient formula, sufficiently true within the limits selected for the work. In deducing it, it was assumed that to produce an image of given diameter, m and t are connected by the relation

$$m = C + 2{\cdot}5 \log t.$$

It will be seen that this is tacitly assumed in the resolutions of the Permanent Committee, and means that (1) increasing the intensity of the source of light is exactly equivalent to increasing the time of exposure in the same proportion, and (2) the magnitude-ratio is the number whose logarithm is 0·4. The quantity C is a function of the diameter, and it was assumed that the diameter increases as some power of the time of exposure. From a comparison of the 30 min. and 6 min. exposures this power was found to be 1/3·46, and from a comparison of the 30 min. and 1 min. exposures, 1/3·17. The value 1/3·3 was adopted in the formula, which thus becomes—

$$m = C' + 2{\cdot}5 \log t - 8{\cdot}3 \log d.$$

Finally, the values of C′, as deduced from the stars available, are as follows :—

Star D.M.	Mag. Arg.	C′ 30 min.	C′ 6 min.	C′ 1½ min.
66°541	6·5	13·51	14·04	14·47
67·538	7·0	13·35	14·51	14·86
66·538	7·8	13·41	13·93	13·93
66·539	8·3	13·59	13·46	13·51
66·548	8·5	14·62	15·12	15·69
66·536	8·8	13·39	13·42	13·53
66·549	8·8	13·99	13·31	12·67
67·520	9·0	14·49	14·85	14·36
66·543	9·1	12·77	12·32	12·49
67·524	9·4	13·91	14·36	14·61
66·546	9·4	14·08	13·91	14·05
66·534	9·5	13·78	14·36	13·67
67·521	9·5	14·23	14·36	13·97
67·523	9·5	13·78	13·88	13·02
67·527	9·5	12·61	13·05	12·22
66·547	9·5	14·16	13·20	13·67
		13·73	13·88	13·80

The value C′=13·80 was thus adopted in the general formula.

From this formula we can deduce the times necessary to obtain stars of a given magnitude on a night actinically similar to 1891 March 4. Mr. Criswick describes this night as "only moderately good, and better at the time of the short exposures than during the long exposure," which accords with the small value of C′ deduced from the long exposure. The night was, however, probably a fair sample of the observing weather which will be available at Greenwich, and the following table will be thus approximately correct:—

Times of Exposure requisite to obtain Discs of given Diameter from Stars of given Magnitude.

Diam. of Disc.	Magnitude.		
	14·0	11·0	9·0
	min.	min.	sec.
6″·0	461	29	277
5·0	252	16	151
4·0	120	7·6	72
3·0	46	2·9	28
2·5	25	1·6	15
2·0	12	0·8	7

It is doubtful whether the formula can be extended much below discs of 3″; the minimum disc visible is something less than 3″ in diameter. A faint photographic disturbance can often be seen with no measurable disc when the place of a star is known from a longer exposure; but for the Chart plates, if the 14th magnitude stars are to be readily discernible, they should probably have a diameter of about 2″·5, and the plates should thus be exposed for about 25^m or 30^m.

By resolutions 19 and 23 the exposures for the Catalogue plates would thus be 2^m and 30^s, but in order to facilitate the work of measurement it may be advisable to give rather longer exposures, say 4^m and 1^m.

The following table shows the diameters of discs of bright stars with exposures of 30^m, 2^m, and 30^s respectively:—

	Magnitude.							
	1	2	3	4	5	6	7	8
min.	″	″	″	″	″	″	″	″
30	97	73	56	42	32	24	18	14
2	43	33	25	19	14	11	8	6
sec.								
30	28	21	16	12	9	7	5	4

These exposures must, of course, be prolonged on bad nights. It is proposed to mount an auxiliary photo-telescope with 4-inch object-glass by Dallmeyer, pointing to *Polaris* or λ *Ursæ Minoris*,

so that during the long exposure of the plate for the star-chart, a test-plate from the same batch of plates may be taken with a series of short exposures on *Polaris* and rapidly developed (say for 1^m with the standard developer) as an indication of the actinic character of the atmosphere, and as a guide to the exposure necessary to give stars to the 14th magnitude on the Chart plates. From preliminary experiments which have been made, it has been found that a faint image of *Polaris* is obtained with an exposure of 2^s with the Dallmeyer 4-inch telescope.

Variations of Latitude deduced from the Observations of Polaris made at Greenwich, 1851–1889. By Professor H. G. van de Sande Bakhuyzen, Foreign Associate.

The accordance existing between the variations of the latitude deduced from observations made in Berlin, Potsdam, and Prague in the years 1889 and 1890 (*Astron. Nachr.* vol. cxxvi. p. 145) is so evident that it is not possible to explain them by accidental errors. One of the most probable systematic errors which might have caused those variations is an inequality of the refraction at equal distances north and south from the zenith, produced either by an anomalous refraction in the observing-room, or by a configuration of the strata of uniform density in the atmosphere, which is not symmetrical north and south of the zenith.

From an investigation of Professor Albrecht and one of my own, it seems, however, that that error cannot be admitted.

Professor Albrecht has shown that from October 1889 to February 1890 the results of the observations of stars at zenith distances from $2^\circ\ 38'$ to $10^\circ\ 32'$ are the same as those from observations of stars whose zenith distances are comprised between $12^\circ\ 46'$ and $26^\circ\ 29'$ (*Astron. Nachr.* vol. cxxvi. p. 158).

By the courtesy of Professor Helmert, I have received the daily results for the latitude given by each pair of stars observed in Berlin, Potsdam, and Prague from January 1889 to April 1890, so that I could calculate for that whole period the latitudes from observations of stars very near to the zenith. I have employed for that purpose twenty-four stars, whose zenith distances, with the exception of two, are smaller than 5° (the mean zenith distance was $2^\circ\ 53'$). Reducing these observations in the same way as has been followed by Professor Albrecht in the reduction of all the observations, I obtained for the mean monthly results the following values. In the third column I have added the results of the observations of all the stars.

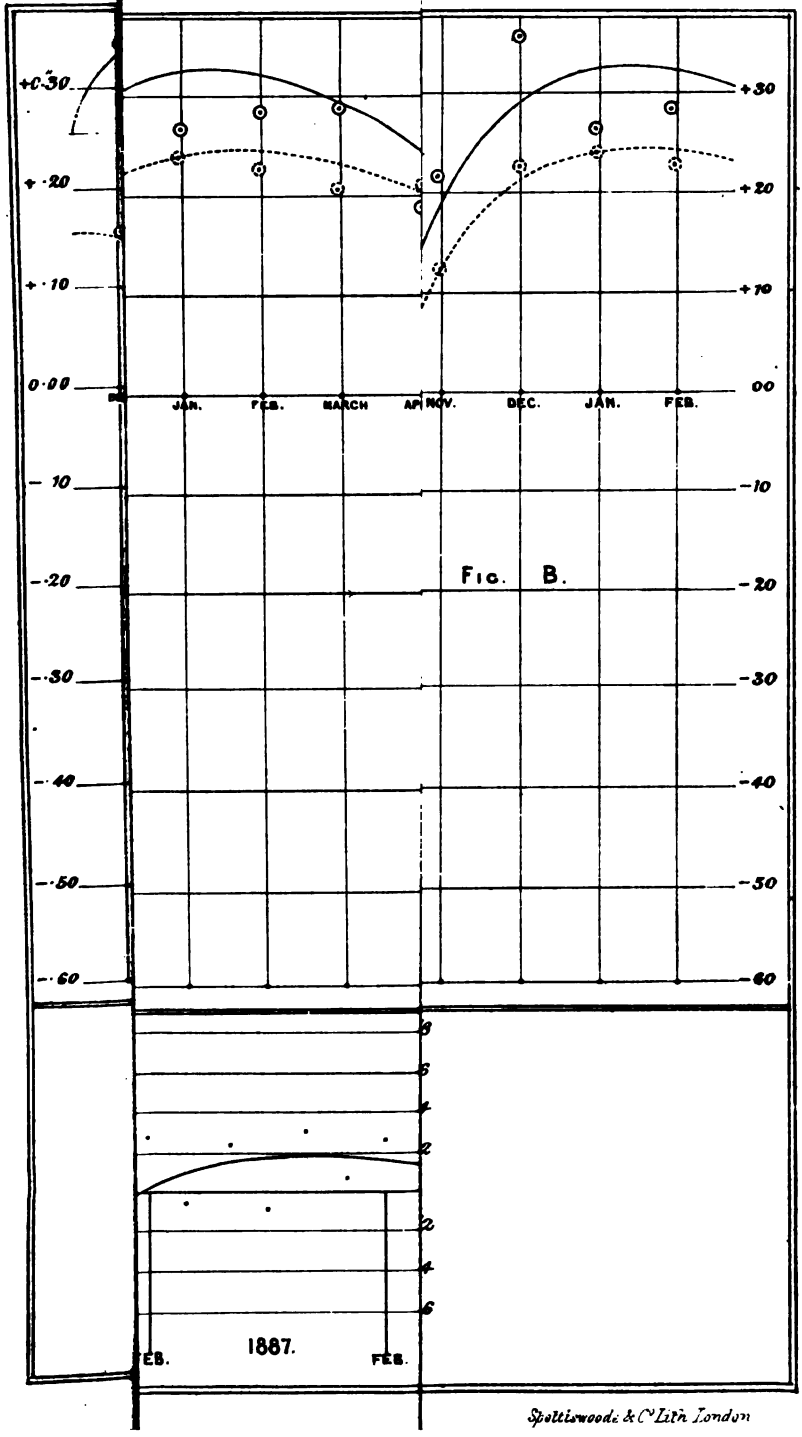


FIG. B.

Spottiswoode & Co Lith London

TABLE I.

	Zenith Stars.	All the Stars.		Zenith Stars.	All the Stars.
	"	"		"	"
1889, Jan.	17·23	17·19	1889, Sept.	17·53	17·51
Feb.	17·33	17·30	Oct.	17·61	17·52
March	17·43	17·29	Nov.	17·42	17·30
April	17·38	17·34	Dec.	17·14	17·10
May	17·44	17·36	1890, Jan.	17·23	17·11
June	17·54	17·40	Feb.	17·18	17·05
July	17·65	17·50	March	17·11	17·07
Aug.	17·68	17·54	April	17·37	17·15

For every month the latitude from stars near the zenith is somewhat greater than that from all the stars, but the variation of the latitude in both cases is about the same. It is not impossible to conceive a configuration of the strata of the air in the atmosphere, which would cause the same anomaly in the refraction for stars at different distances from the zenith, but it is very improbable that in Berlin, Potsdam, and Prague the strata had at the same time exactly that configuration.

In this state of the question it is of great interest to examine: (1) whether in other observatories the same variation has been observed, (2) whether those variations have a periodic character and had the same values a certain number of years ago.

The best material, particularly for examining the second question, is offered by the observations of zenith distances with the transit circle at Greenwich, which from 1851 till now have been made always in the same manner and under the same conditions. The only change of the instrument was made in August and September 1865, when the opposite sides of the central cube were pierced with perforations; but an influence of that operation on the results of the observations I used is not indicated.

I used for my purpose only the observations of the zenith distances of *Polaris*, because their number is very great and distributed over the whole year, and because by the combination of zenith distances in both culminations one can get results free from the influence of aberration, parallax, &c.

The polar distances of *Polaris* show a strongly-marked annual variation, which has been pointed out by me in 1868 (*Astron. Nachr.* vol. lxxii. p. 241), by Mr. Downing in 1880 (*Monthly Notices R.A.S.* vol. xl. p. 430), by Mr. Thackeray in 1888 and 1889 (*Memoirs R.A.S.* vol. xlix. p. 239, and *Monthly Notices R.A.S.* vol. l. p. 15). That variation is not the same in both culminations; it is therefore certain that it is not wholly the result of a real change in the latitude, and it is, in the first place, necessary to investigate what is probably its cause.

From the interesting discussion published by Mr. Thackeray

and from the paper I published in the *Astron. Nachr.* it is highly probable that at least a part of the variation is connected with the temperature. Mr. Thackeray discusses the following hypotheses as most likely to furnish a possible cause of the annual variation:—

1. That the readings of the thermometer, used in the reductions, may be liable to periodic error owing to position.

2. That the method of adopting the zenith-point correction may lead to periodic error.

3. That the discordances of observation may vary directly with temperature.

4. That the discordances of observation may vary directly with humidity.

In his paper in the *Memoirs R.A.S.* he comes to the following conclusions: that the corrections deduced from the first hypothesis, though making the final results more accordant, do not materially alter the run of the annual variation; that the differences of values between zenith points, derived from the nadir-point observations and from the mean of $\frac{R+D}{2}$ of the North and South reflexion stars, do not satisfy the purposes of his inquiry; that it is possible to explain the discordances by the third and fourth hypotheses, but that there seems to be no means of determining whether the discordances arise from an imperfect correction for changes of temperature, or to the want of a correction for variations in the amount of humidity.

In his paper in the *Monthly Notices R.A.S.* Mr. Thackeray publishes a continuation of his researches, particularly on the influence of temperature and humidity on refraction. From an examination of the results of the polar distances of *Polaris* and the Sun, he states (page 18) that the results of his inquiry "gave no assurance that either correction (for temperature and humidity) was an unmixed advantage." He then determined to see what "effect these corrections would have on the observations of low southern stars, and the answer is apparently decisive; the observed places will allow of neither the one nor the other correction."

At last (page 21) he "assumes that the discordances are not connected with the correction for refraction, that they are still due to temperature, and probably closely connected with changes in the instrument itself, and that they vary as the sin. Z.D."

At the end of his paper he concludes: "A correction depending on temperature, and varying as sin z., will satisfy the discordances in the observations of *Polaris*, it will get rid of an annual variation, also apparently depending on temperature, in the tabular errors of the Sun; as far as it goes, it will tend to bring into greater accordance the errors derived from low southern stars, when arranged in order of temperature, and it will diminish the sum of the squares of the residuals of the R—D formula."

Mr. Thackeray has founded his conclusion, "A correction depending on temperature will satisfy the discordances in the observations of *Polaris*," on the *mean* values of those discordances at equal temperatures in *both* culminations, but that conclusion does not hold good when we consider the culminations *separately*.

In the following table are contained the mean monthly discordances of *Polaris* for the period 1851–1882, and also the mean readings of the ordinary exterior thermometer, taken at the time of observation of *Polaris* and *Polaris* S.P. for the years 1851–1858, from Mr. Thackeray's paper in the *Memoirs R.A.S.* The discordances represent errors of zenith distance. The first of the two series of discordances for each culmination in this table represents the values deduced from the daily results for each year, published in the Greenwich Observations without any correction; the second series represents the same values when they are reduced with a coefficient of aberration 0″·07 greater than Struve's coefficient. According to the researches of Nyrén and Küstner, this correction of the coefficient of aberration is probable.

TABLE II.

	Upper Culmination.				*Lower Culmination.*		
		Discordances.				Discordances.	
	Exterior therm.	Uncorr.	Corrected for Aberration.		Exterior therm.	Uncorr.	Corrected for Aberration.
	°	″	″		°	″	″
Jan.	39·3	+0·37	+0·30	Jan.	31·3	+0·20	+0·27
Feb.	41·3	−0·07	−0·12	Feb.	31·5	+0·24	+0·29
March	49·2	−0·21	−0·23	March	35·8	+0·27	+0·29
April	54·2	−0·51	−0·50	April	42·0	+0·20	+0·19
May	57·3	−0·35	−0·31	May	49·2	+0·21	+0·17
June	61·8	−0·35	−0·29	June	64·4	+0·08	+0·02
July	55·2	+0·07	+0·14	July	71·9	−0·42	−0·49
Aug.	54·3	+0·01	+0·06	Aug.	71·2	−0·51	−0·56
Sept.	50·2	+0·06	+0·08	Sept.	67·8	−0·44	−0·46
Oct.	47·8	+0·14	+0·13	Oct.	54·4	−0·13	−0·12
Nov.	38·5	+0·21	+0·17	Nov.	40·1	+0·18	+0·22
Dec.	36·8	+0·40	+0·34	Dec.	36·0	+0·30	+0·36

For *Polaris* S.P. there is generally a fair agreement between the discordances and the temperature, with the exception of the two months May and June, for which the observed discordances are about 0″·25 and 0″·40 greater than they should be from the temperatures; but for *Polaris* in upper culmination the same accordance does not exist. The maximum of the discordances occurs

in April, the maximum temperature in June. The discordances at equal temperature in March and September are $-0''.21$ ($-0''.23$) and $+0''.06$ ($+0''.08$), and in April and August $-0''.51$ ($-0''.50$) and $+0''.01$ ($+0''.06$). From these numbers it is clear that it is not possible to represent the discordances in both culminations by an expression depending only on the exterior temperature.

As the proposed hypotheses did not give satisfactory results, I continued my researches in the direction of my paper in the *Astron. Nachr.* vol. lxxii., and have sought the relation between the discordances and the excess of exterior over interior temperature. I employed in that discussion the observations of the years 1851–1882. I should have liked to extend my researches also over the observations in following years, but from 1883 there are but very few readings of the interior thermometer, so that the excess of the exterior over the interior temperature could not be determined.

In the first place I calculated, when possible, from the readings of the interior and exterior thermometer in the "Observations of Zenith Distances" the excess of temperature for each observation of *Polaris*, and formed for *Polaris* and *Polaris* S.P. separately the following values:—

1. The mean value Q of the zenith distances with a positive excess of temperature.

2. The mean value R of the zenith distances with a negative excess of temperature.

3. The mean annual value P of all the zenith distances for which the excess of temperature could be indicated.

4. The mean monthly values P_1, $P_2 \ldots P_{12}$ of the zenith distances for which the excess of temperature could be indicated.

At the same time I formed in the four cases the mean values of the excesses of temperature B, C, A, A_1, $A_2 \ldots A_{12}$.

In Table III. are given the differences R − Q with the differences of the mean excesses of temperature C—B for each year and their weights, the weight of one observation being taken as unity.

TABLE III.

Upper Culmination.				*Lower Culmination.*			
Year.	R−Q	C−B	Weight.	Year.	R−Q	C−B	Weight.
	″	°			″	°	
1851	+0·27	6·6	9	1851	+0·45	5·6	13
1852	+0·82	6·5	14	1852	+0·66	5·8	15
1853	+0·74	6·3	7	1853	+0·68	5·8	11
1854	+0·23	6·3	17	1854	+0·50	6·2	19
1855	+1·06	6·2	11	1855	+0·84	5·3	13
1856	+0·52	6·0	15	1856	+0·74	7·2	14
1857	+0·72	7·4	18	1857	+0·34	6·1	20
1858	+0·61	8·0	24	1858	+0·48	5·6	19
1859	+0·34	6·0	14	1859	+0·65	6·2	15
1860	+0·61	6·7	9	1860	+0·72	6·8	5
1861	−0·11	5·7	17	1861	+0·20	5·3	13
1862	+0·23	5·5	7	1862	+0·04	4·7	11
1863	+0·32	5·5	13	1863	+0·66	5·8	13
1864	+0·59	5·5	14	1864	+0·91	5·7	15
1865	+0·35	6·8	13	1865	+0·27	4·6	10
1866	+0·32	6·7	8	1866	+0·29	4·0	3
1867	+0·43	5·7	7	1867	+0·06	3·6	6
1868	+0·65	5·7	15	1868	+0·36	7·0	20
1869	+0·59	6·1	8	1869	+0·97	6·7	16
1870	+1·01	8·3	17	1870	+0·93	6·3	14
1871	+0·25	8·3	9	1871	+0·89	5·8	14
1872	+0·51	6·9	15	1872	+0·61	6·4	17
1873	+0·56	6·8	16	1873	+0·48	6·6	18
1874	+1·21	6·7	13	1874	+0·48	5·9	12
1875	+0·46	6·2	9	1875	+0·82	6·1	10
1876	+1·31	6·4	12	1876	+0·83	6·5	13
1877	+0·72	5·7	11	1877	+0·55	4·9	17
1878	+0·52	6·8	8	1878	+0·83	5·8	13
1879	+0·65	6·0	11	1879	+0·58	4·4	9
1880	+0·25	4·9	11	1880	+0·56	6·2	11
1881	+0·95	6·8	11	1881	+0·24	5·8	12
1882	+1·17	6·3	8	1882	+0·68	5·5	7

Taking the mean value of all the years, without regard to the weights, we obtain:—

	R−Q	C−B
Polaris	0″60	−6°4
Polaris S.P.	0·57	−5·8

The observations of the years 1851–1864 (discussed *Astron. Nachr.* vol. lxxii.) gave:—

	R−Q	C−B
Polaris	0″49	−6°4
Polaris S.P.	0·55	−5·9

The piercing of the cube in 1865 had accordingly no appreciable influence on these results.

In order to study further the relation between the discordances and the excesses of temperature, I formed for each year the differences P_1-P, P_2-P . . . A_1-A, A_2-A . . . of the annual and the monthly mean values. The weights of these differences for some months are very small; it is therefore desirable to take the means of different years. In combining the results of consecutive years the influence of a real periodic variation of latitude depending on the Eulerian period of 304 days disappears, but as 6×304 days is very nearly equal to five years, the influence of such a variation is each fifth year the same. I have therefore formed the mean monthly discordances for the years 1851, 1856, 1861, for the years 1852..., 1857, 1862..., for the years 1853, 1858, 1863..., for the years 1854, 1859, 1864..., and for the years 1855, 1860, 1865....

Those five series of monthly discordances, with their weights, are contained in Table IV.

TABLE IV.

Upper Culmination.

	1851, 56 . . . 81			1852, 57 . . . 82			1853, 58 . . . 78			1854, 59 . . . 79			1855, 60 . . . 80		
	Discordance.	Excess of Temp.	Weight.	Discordance.	Excess of Temp.	Weight.	Discordance.	Excess of Temp.	Weight.	Discordance.	Excess of Temp.	Weight.	Discordance.	Excess of Temp.	Weight.
	″	°		″	°		″	°		″	°		″	°	
Jan.	+0.41	−1.8	30.3	+0.21	−1.1	36.6	+0.41	−1.0	35.9	+0.47	−1.1	29.1	+0.39	−1.1	29.7
Feb.	+0.09	+0.1	17.8	+0.04	+0.7	19.0	−0.13	+0.7	25.9	−0.22	+0.5	21.5	−0.08	+0.6	29.4
Mar.	−0.16	+2.0	31.3	−0.25	+3.1	26.8	−0.20	+3.7	32.7	−0.31	+2.5	31.9	−0.14	+1.6	23.9
Apr.	−0.37	+3.0	32.1	−0.63	+4.2	31.3	−0.40	+4.4	25.0	−0.62	+4.1	31.5	−0.52	+5.0	35.5
May	−0.41	+4.6	40.7	−0.46	+5.2	24.9	−0.24	+4.3	27.8	−0.13	+3.6	29.5	−0.49	+4.4	27.9
June	−0.16	+3.8	25.7	−0.46	+4.1	25.7	−0.45	+4.1	26.9	−0.37	+3.3	23.1	−0.27	+3.7	21.2
July	−0.12	−2.0	13.3	+0.24	−2.3	17.6	+0.04	−1.3	17.7	−0.07	−0.8	20.4	+0.39	−1.0	9.1
Aug.	+0.05	−3.2	13.0	+0.07	−2.0	10.5	−0.24	−4.0	17.8	−0.08	−3.1	18.2	+0.34	−2.8	14.0
Sept.	+0.16	−2.6	34.3	−0.04	−2.5	34.6	−0.06	−2.5	38.7	+0.06	−2.4	32.1	+0.17	−3.3	37.8
Oct.	−0.05	−2.2	40.2	+0.22	−2.2	51.7	+0.13	−2.2	46.4	+0.34	−2.1	39.5	+0.04	−2.2	32.0
Nov.	+0.27	−1.3	42.2	+0.18	−1.5	36.6	+0.18	−1.8	38.9	+0.14	−1.6	44.0	+0.32	−2.3	26.4
Dec.	+0.32	−2.4	34.6	+0.48	−1.5	36.6	+0.48	−1.9	33.5	+0.32	−1.3	39.0	+0.43	−1.3	21.1

Lower Culmination.

	1851, 56 . . . 81			1852, 57 . . . 82			1853, 58 . . . 78			1854, 59 . . . 79			1855, 60 . . . 80		
	Discordance.	Excess of Temp.	Weight.	Discordance.	Excess of Temp.	Weight.	Discordance.	Excess of Temp.	Weight.	Discordance.	Excess of Temp.	Weight.	Discordance.	Excess of Temp.	Weight.
	″	°		″	°		″	°		″	°		″	°	
Jan.	+0.12	−5.1	8.0	−0.07	−2.2	16.8	+0.88	−3.3	8.7	+0.58	−1.4	7.7	−0.54	−1.5	4.7
Feb.	+0.23	−2.6	9.5	+0.06	−2.8	11.2	−0.06	−2.9	10.1	+0.50	−2.5	11.2	−0.20	−1.5	7.7
Mar.	+0.29	−2.7	27.5	+0.25	−2.2	14.9	+0.09	−2.7	38.1	+0.33	−2.0	36.6	+0.54	−1.8	16.0
Apr.	+0.16	−2.2	40.0	+0.10	−2.4	53.7	+0.20	−2.6	47.8	+0.32	−2.1	48.1	+0.22	−2.4	45.5
May	+0.13	−1.8	54.6	+0.29	−1.4	55 1	+0.22	−2.2	46.7	+0.17	−1.7	64.3	+0 26	−1.7	47.8
June	+0.10	+0.7	42.8	+0.09	+0.4	41.8	−0.10	+0.4	49.1	+0.19	+0.5	37.2	+0.15	+0.4	42.5
July	−0.49	+3.9	32.6	−0.60	+4.1	37 6	−0.28	+4.4	38.2	−0.45	+4.4	28.0	−0.23	+3.1	19 6
Aug.	−0.24	+3.6	38.2	−0.51	+4.4	26.9	−0.43	+4.2	39.0	−0.95	+5.2	31.0	−0.50	+4.7	20.1
Sept.	−0.61	+2.9	24.2	−0.24	+3.0	33.1	−0.46	+3.3	35.4	−0.38	+3.3	35.0	−0.62	+3.3	26.2
Oct.	−0.05	+1.2	35.2	−0.09	+0.9	38.5	+0.09	+0.2	30.5	−0.24	+1.2	36.0	−0.45	+1.3	22.9
Nov.	+0.28	−1.5	32.5	+0.13	−0.9	29.5	+0.36	−2.2	23.4	+0.03	−1.2	35.5	+0.16	−0.8	16.6
Dec.	+0.33	−2.7	14.0	+0.02	−2.0	26.0	+0.37	−2.6	21.5	+0.22	−2.4	26.1	+0.46	−3.4	10.1

If there is a variation of latitude depending on the motion of the instantaneous axis of rotation in 304 days, the discordances of the same months in the different series must show a periodic difference. A mere inspection of these numbers gives no indication of such differences, and that a variation in the ten-month period, if existing, is very small, is also indicated by a discussion of the mean error of weight unity.

I determined first that mean error from the differences of the monthly discordances for the years 1851, 1856, 1861..., and their mean values in the first column of Table IV. and also from the like differences for the other years. The mean value for *Polaris* and *Polaris* S.P. is:—

Mean error ± 0″·89, prob. error ± 0″·60.

Afterwards I determined the mean error from the differences of the mean monthly discordance for each series in Table IV. and their general mean values. I obtained then for *Polaris* and *Polaris* S.P.—

Mean error ± 0″·78, prob. error ± 0″·53.

If there was a systematic difference between the mean monthly discordances in Table IV., the second value of the mean error should be greater than the first, instead of smaller.

The excesses of temperature in the same months of the different year are not the same; and as it seems that the discordances are nearly proportional to the excesses, I have, in the calculation of the mean errors, added to the discordances for the same month a slight correction in order to reduce them to the same excess.

Another determination of the probable error of a zenith distance of *Polaris* is given by Sir G. B. Airy in his "Theory of Errors of Observation," second edition, page 115. He finds—

Probable error ± 0″·57.

I have adopted as the mean error of weight unity—

± 0″·84.

Taking the mean values of the discordances of the same month in the five series of Table IV. with equal weights, the results are entirely free from a periodic variation in 304 days, and there remains but a small influence of the periodic variation indicated by Radau (*Comptes Rendus*, vol. cxi. No. 16) and Helmert (*Astron. Nachr.* vol. cxxvi. p. 217), depending on the motion of the instantaneous axis of rotation around a principal axis of inertia and an annual motion of that principal axis of inertia. As the amount of that periodic variation in 304 days is, however,

as we have seen, very small, we will get more exact results, which are also practically free from the influence of that periodic variation, in combining the partial results in Table IV. with their weights.

The resulting mean values of the discordances with the excesses of temperature and their weights are contained in Table V. I have added in that table for each culmination another column, containing the mean discordances corrected for a slight variation in the coefficient of aberration. It is, as I have already said, probable from the recent researches of Nyrén and Küstner that the true coefficient of aberration is about 20″·51; the coefficient used in the reduction of the Greenwich observations from 1851 to 1856 is 20″·4200, and since the latter year 20″·4451; the mean value for all the years is therefore 20″·440. The numbers in the third column for each culmination represent the discordances corrected for a variation +0″·07 in the coefficient of aberration, or reduced to a value 20″·51 of that coefficient.

TABLE V.

Upper Culmination.

	Discordance. Uncorrected.	Discordance. Corrected for Aberration.	Excess of Temp.	Weight.
	″	″	°	
Jan.	+0·37	+0·30	−1·3	161·6
Feb.	−0·07	−0·12	+0·5	113·6
March	−0·21	−0·23	+2·6	146·6
April	−0·51	−0·50	+4·2	155·4
May	−0·35	−0·31	+4·4	150·8
June	−0·35	−0·29	+3·8	122·6
July	+0·07	+0·14	−1·5	78·1
Aug.	+0·01	+0·06	−3·1	74·3
Sept.	+0·06	+0·08	−2·6	177·5
Oct.	+0·14	+0·13	−2·2	209·8
Nov.	+0·21	+0·17	−1·7	188·1
Dec.	+0·40	+0·34	−1·7	164·8

Lower Culmination.

	Discordance. Uncorrected.	Discordance. Corrected for Aberration.	Excess of Temp.	Weight.
	"	"	°	
Jan.	+0·20	+0·27	−2·7	45·9
Feb.	+0·24	+0·29	−2·5	49·7
March	+0·27	+0·29	−2·3	133·1
April	+0·20	+0·19	−2·3	235·1
May	+0·21	+0·17	−1·7	268·5
June	+0·08	+0·02	+0·5	213·4
July	−0·42	−0·49	+4·1	156·0
Aug.	−0·51	−0·56	+4·4	155·2
Sept.	−0·44	−0·46	+3·2	153·9
Oct.	−0·13	−0·12	+1·0	163·1
Nov.	+0·18	+0·22	−1·4	137·5
Dec.	+0·30	+0·36	−2·5	97·7

In order to see more clearly the connection between those corrected discordances and the excesses of temperature, I have represented both in the following plate (Plate 3, A, B), the first by a continuous, the second by a dotted, line. The negative excesses are drawn in the same direction as the positive values of the discordances, and 1° Fahrenheit and 0″·09 are represented by lines of the same length.

From these curves it is clear, that but a small part of the discordances can be explained by a real variation of latitude, but that there exists a close connection between the discordances and the excesses of temperature, which could be explained by a refraction of the light in entering the observing-room, as I have more fully shown in the *Astron. Nachr.* vol. lxxii.

The discordances can be tolerably well represented by the formula −0″·09 × excess of temperature, but there are still differences greater than the accidental errors. In the hypothesis that the discordances are due to refraction in the observing-room, these differences may be explained by the supposition that the differences of the exterior and interior thermometer are not equal or proportional to the differences of temperature of the air strata, which cause the refraction, or by the supposition that the form of the strata of equal temperature does not remain the same throughout the year. The inspection of the curves for upper culmination from July to December, when the excesses of temperature have about the same values, the discordances on the contrary show differences of 0″·3, and the comparison of the discordances for upper transit in July, August, September, and October, and for lower transit in

November, December, January, February, and March, which have a mean difference of 0″·17 notwithstanding the mean excesses of temperature are about the same, are not favourable for both suppositions, and a more probable explanation is found in the supposition that the differences are caused by a small real variation of the latitude. Adopting that the part of the discordances depending on the excesses of temperature is represented by 0″·09 × excess of temperature, the remaining differences, with their mean errors, are represented in Table VI.

TABLE VI.

	Upper Culmination.		*Lower Culmination.*		
	Discordance corrected for Temp.	Mean Error. ±	Discordance corrected for Temp.	Mean Error. ±	Mean Discordance U.C. and L.C.
	″	″	″	″	″
Jan.	+0·18	0·07	+0·03	0·12	+0·10
Feb.	−0·08	0·08	+0·07	0·12	−0·01
Mar.	0·00	0·07	+0·08	0·07	+0·04
Apr.	−0·12	0·07	−0·02	0·05	−0·07
May	+0·09	0·07	+0·02	0·05	+0·05
June	+0·05	0·08	+0·06	0·06	+0·05
July	+0·01	0·10	−0·12	0·07	−0·06
Aug.	−0·22	0·10	−0·16	0·07	−0·19
Sept.	−0·15	0·06	−0·17	0·07	−0·16
Oct.	−0·07	0·06	−0·03	0·07	−0·05
Nov.	+0·02	0·06	+0·09	0·07	+0·05
Dec.	+0·19	0·07	+0·14	0·08	+0·16

Only in four months the differences for the two transits are 0″·01 greater than their mean errors; in the other months they are much smaller. When we do not adopt 0″·09, but another value for the coefficient of the excesses of temperature, the agreement between the two culminations will be not so good, but their mean values will not be altered very much.

The parallax of *Polaris* has a small influence on the discordances, but its value is too uncertain to employ it in the reductions.

The numbers in the last column of Table VI. would indicate that the latitude has a minimum in December or January, and a maximum in August or September, about the same epochs as have been deduced from the observations at Berlin, Potsdam, Prague, 1889 and 1890.

We may sum up the conclusions of the interesting researches of Mr. Thackeray and of the first part of my investigation in the following manner:—

1. The monthly discordances in the zenith distances of *Polaris* are for the greater part not caused by a real variation of latitude, but chiefly by an effect of temperature.

2. It is not possible to explain those discordances by an error in the indications of the exterior thermometer, or by an influence depending only on the exterior temperature.

3. The discordances can be explained, for the greater part, by a cause depending on the difference of the exterior and interior temperatures.

4. Probably that cause is a refraction in the observing-room, and its effects are sensibly proportional to those differences of temperature.

5. The discordances corrected for that refraction are about the same for both culminations, and can be explained by a real variation of latitude.

If we assume that the probable causes of the discordances indicated under 4 and 5 are the real ones, and we adopt, after Radau and Helmert, the coexistence of an annual variation in the position of the axis of inertia, and the motion of the instantaneous axis of rotation round that axis of inertia, we may calculate one of the co-ordinates of the curve described by the pole of rotation on the surface of the Earth.

I used for this computation the results of Table IV., which I corrected for the influence of refraction in the observing-room by the formula $0''{\cdot}09 \times$ excess of temperature.

The mean values, with equal weights, of the corresponding numbers in both series offered 60 values for the variation of latitude free from parallax, aberration, &c.

The formula 4 for u' or v' given by Helmert (*Astron. Nach.* vol. cxxvi. p. 220) may be written:—

$$u = A \sin mt + B \cos mt + C \sin \mu t + D \cos \mu t,$$

where m is the mean annual motion of the Earth, and μ the mean value of the motion of the instantaneous axis of rotation in the ten-month period.

When the unit of t is a mean month, m is 30° and μ 36°. As the numbers in Table IV. are given about for the 15th of each month, the values of t are reckoned from January 15 of one of the years 1851, 1856, 1861, and so on.

The solution of the resulting 60 equations with their weights, by the method of least squares, gives the following results with their mean errors:—

$$\begin{aligned} A &= 0''{\cdot}0358 \quad \pm 0''{\cdot}0192 \\ B &= 0''{\cdot}0822 \quad \pm 0''{\cdot}0231 \\ C &= 0''{\cdot}0071 \quad \pm 0''{\cdot}0208 \\ D &= -0''{\cdot}0047 \quad \pm 0''{\cdot}0207 \end{aligned}$$

Substituting these values in the original equations, we find for the mean error of weight unity—

$$\pm 0''{\cdot}90.$$

The fair accordance of this value and of those found formerly in a different manner increases the probability of the suppositions which conducted to that result.

The mean errors of C and D are much greater than the computed values of C and D, so that we may safely put C and D equal to zero; the resulting formula for the variation of latitude is then—

$$u = 0''\cdot0358 \sin mt + 0''\cdot0822 \cos mt;$$

or—

$$u = 0''\cdot0897 \cos (mt - 23^\circ\ 30').$$

When t is expressed in days, from January 15, and $m \frac{360}{365\cdot25}$, we have—

$$u = 0''\cdot0897 \cos m\,(t - 23\tfrac{5}{6});$$

or reckoning t from January 0, the variation of the latitude is—

$$u = 0''\cdot09 \cos m\,(t - 39).$$

The latitude has then a minimum on February 9, and a maximum on August 9. The mean error of the constant $0''\cdot09$ of the annual variation is—

$$\pm 0''\cdot0224.$$

The epochs of maximum- and minimum-latitude correspond very nearly with those deduced from the observations made at Berlin, Potsdam, and Prague, 1884–1885, and 1889–1890, but the amplitude of the variation is much smaller. I have, therefore, endeavoured to deduce the variation of latitude for the same years from the Greenwich Observations. I used in this investigation, for the years 1883–1888, the mean north polar distances of *Polaris* in both culminations published in the Greenwich Observations; for the year 1889 and the first two months of 1890 the Astronomer Royal put, with the greatest kindness, the data at my disposal.

The readings of the interior thermometer for those years are with few exceptions not published in the Greenwich Observations, so that I could not determine exactly the excesses of temperature for the different observations. I have therefore adopted for the mean monthly excesses the values published in Table V.

The observations of the years 1883–1889 are all reduced in the same manner, with the same colatitude and refraction, but there is a slight change in the instrument. At the end of 1885 new screws of steel instead of gunmetal were applied by Mr. Simms to the six micrometers of the reading microscopes. The introduction of these new screws has altered the zenith point deduced from nadir observations; but as the method of forming the adopted zenith points consists practically in reducing the zenith point, deduced from the reflected image of the wire, to the mean of the zenith points, deduced from observations of the direct and

reflected images of stars north and south of the zenith, the adopted zenith points depend on the mean of the readings of very different parts of the screws, and will be therefore free from the systematic errors of the screws.

I reduced, therefore, without any correction, all the observations from 1883 to 1889 to the same mean equinox of 1885·0, determined the mean values of the polar distances of *Polaris* in both culminations for the five years 1883–1887, and formed the differences of these values and the mean monthly results of the different years. I added to those differences the correction for the excess of temperature by the formula—

$$0''{\cdot}09 \times \text{excess of temperature in degrees.}$$

In order to obtain results with greater weights, I took the mean values for January and February, March and April, and so on, and combined afterwards the results for upper and lower transits, so that the resulting numbers represent the discordances of latitude. These values, with their weights, are represented in Table VII.

TABLE VII.

	Discordance corrected for Temp.	Weight.		Discordance corrected for Temp.	Weight.
1883.	″		1886.	″	
Feb.	−0·07	13·8	Oct.	−0·41	24·5
Apr.	+0·02	27·4	Dec.	+0·04	16·8
June	−0·12	31·1	1887. Feb.	+0·29	10·8
Aug.	−0·32	23·3	Apr.	−0·06	15·8
Oct.	−0·41	29·4	June	+0·25	29·3
Dec.	+0·03	31·1	Aug.	−0·08	23·5
1884. Feb.	−0·08	13·8	Oct.	+0·32	23·4
Apr.	−0·32	23·6	Dec.	+0·08	21·7
June	−0·32	38·7	1888. Feb.	+0·27	7·9
Aug.	−0·58	14·7	Apr.	+0·28	9·0
Oct.	−0·32	27·5	June	−0·04	29·2
Dec.	−0·34	23·6	Aug.	+0·03	5·0
1885. Feb.	+0·48	10·0	Oct.	+0·09	26·4
Apr.	+0·25	33·2	Dec.	+0·35	23·5
June	+0·66	31·2	1889. Feb.	+0·20	6·0
Aug.	+0·25	15·7	Apr.	+0·51	13·7
Oct.	−0·38	19·8	June	+0·32	29·4
Dec.	−0·08	16·9	Aug.	−0·14	14·5
1886. Feb.	+0·68	12·8	Oct.	+0·11	23·3
Apr.	+0·33	21·5	Dec.	+0·41	13·7
June	+0·11	26·3	1890. Feb.	+0·78	12·6
Aug.	−0·08	10·0			

The numbers of this table have been laid down in a graphical representation, and fig. C shows the variation of latitude from February 1883 to February 1890.

From the table and the diagram it seems that there is a great difference between the latitude in the year 1884 and the beginning of 1885. In both years the same elements of reduction, the same refraction, and the same errors of division have been used. The correction to the direct and reflexion observations, deduced from the discordances of reflexion and direct results (the flexure included), is—

1884, Dir. Obs. $-0''.026+0''.658$ sin Z.D.
Refl. Obs. $+0''.026-0''.498$ sin Z.D.
1885, Dir. Obs. $-0''.018+0''.687$ sin Z.D.
Refl. Obs. $+0''.018-0''.527$ sin Z.D.

The correction to each nadir observation, in order to reduce them to the mean of North and South stars, is in 1884 $-0''.45$, in 1885 $-0''.36$. In the adopted zenith points the nadir observations enter with a weight 1, and the star observations with a weight 4, so that the difference of the two corrections has no appreciable influence on the zenith points.

There is therefore no reason to seek the cause of the differences of the results in both years in the reductions, and it is very probable that they are caused by a real variation of latitude.

It seems also that there has been a variation of latitude in the years 1889–1890, with a maximum in August. The mean errors of the results in Table VII. are—

1889 February	$\pm 0''.34$	1889 October	$\pm 0''.18$
April	0.23	December	0.23
June	0.16	1890 February	0.24
August	0.22		

They show that, though the variation of latitude is not certain, it is, however, probable. The variations in 1884–1885 and 1889–1890 agree well with those found in Germany.

From this part of the investigation we may conclude—

1. That it is probable that the observations of *Polaris* at Greenwich confirm the variations of latitude observed elsewhere in 1884–1885 and 1889–1890.

2. That there is a very strong probability that the variations in these years had an exceptional character, and do not agree with the annual variations, deduced from the observations of *Polaris* at Greenwich during the period 1851–1882.

This last point may have some interest, as it indicates that there has been probably some perturbation in the position of the principal axis of inertia. A slight perturbation will, however, be sufficient to explain the greater amplitude of the variation.

Helmert assumes in his interesting paper (*Astron. Nachr.* vol. cxxvi.) that the pole of the principal axis of inertia (pole of inertia) has an annual elliptic motion around its mean place (centre); its co-ordinates are—

$$x = p \cos(mt + r); \; y = q \sin(mt + r).$$

The co-ordinates of the pole of the instantaneous axis of rotation (pole of rotation) are then—

$$u = \frac{\mu^2 p + \mu m q}{\mu^2 - m^2} \cos(mt + r) + A \cos(\mu t + B);$$

$$v = \frac{\mu^2 q + \mu m p}{\mu^2 - m^2} \sin(mt + r) + A \sin(\mu t + B).$$

When we admit, as is probable, q equal to zero, or the motion of the pole of inertia rectilinear; and we put A=0, as we deduced from the Greenwich Observations, we have for $mt+r=0$—

$$x = p; \; y = 0; \; u = p\frac{\mu^2}{\mu^2 - m^2}; \; v = 0.$$

The pole of inertia and the pole of motion are, therefore, at the same instant in a straight line with the centre, and at their greatest elongations; the proportion of their distances to the centre is—

$$1 : \frac{\mu^2}{\mu^2 - m^2}.$$

When we further make the hypothesis that by meteorological processes the pole of inertia remains some time, say 2·5 months, in that greatest elongation, it is easy to calculate the motion of the pole of rotation. During the 2·5 months it will describe around the pole of inertia an arc of 90° with a radius

$$p\frac{m^2}{\mu^2 - m^2};$$

and when, from the end of that period of 2·5 months, the pole of inertia begins again its rectilinear annual motion, we must give to A and B such values that for $mt+r=0$ we have—

$$u = p \text{ and } v = p\frac{m^2}{\mu^2 - m^2}.$$

We find then—

$$B = 135° + \frac{\mu}{m} r; \; A = p\frac{m^2\sqrt{2}}{\mu^2 - m^2}.$$

From the Greenwich Observations we deduce that 0″·09 lies between:

$$p\frac{\mu^2}{\mu^2 - m^2} \text{ and } p\frac{\mu m}{\mu^2 - m^2},$$

or putting for μ and m their values, 0″·09 lies between $\frac{36}{11}p$ and $\frac{30}{11}p$; p will be therefore nearly 0″·03 and A 0″·096.

The co-ordinates of the pole of rotation are then—

$$u = 0''{\cdot}098 \cos(mt + r) + 0''{\cdot}096 \cos(\mu t + 135° + \frac{\mu}{m} r);$$

$$v = 0''{\cdot}098 \sin(mt + r) + 0''{\cdot}096 \sin(\mu t + 135° + \frac{\mu}{m} r).$$

The greatest distance of the pole of rotation from the centre is now $0''{\cdot}194$ instead of $0''{\cdot}09$.

Leiden: 1891 *March.*

Addendum.

In answer to some remarks which Mr. Thackeray has had the courtesy to address to me, I add the following:—

In my paper I said that Mr. Thackeray based the conclusions in his last paper in the *Monthly Notices*, vol. l., on the mean of the polar distances of *Polaris* in upper and lower culmination, because in that paper, wherein he gives the result of "a more careful discussion of the lower and higher temperatures, and an extension of the range of temperature in the latter direction," he communicates only these means. Mr. Thackeray writes me that he has, however, satisfied himself as to the fair agreement of the result of both culminations; but as the monthly discordances, particularly of the upper culmination, I communicated in my paper, cannot be fairly represented by an error proportional to the temperature, I must conclude that the agreement between temperature and discordance found by Mr. Thackeray is an accidental one, and that the real cause of the discordances is not the exterior temperature, but must be sought elsewhere. I have also tried to represent the monthly discordances by a term proportional to the temperature and a real variation of latitude (naturally the same for both culminations), but I could not obtain satisfactory results.

In the year 1875 a re-examination of the values of successive revolutions of the screws of the microscope micrometers indicated a decided inequality in those values ("Christie, On the Effect of Wear in the Micrometer Screws of the Greenwich Transit Circle," *Monthly Notices*, vol. xxxvii. p. 18). The conclusion arrived at by Mr. Christie is "that it would appear that by far the greater portion of the wear in the micrometer screws has taken place in the seventeen years preceding 1868, and that, except in the part between 0^r and 1^r, the errors have not sensibly changed since that date."

As my results depend only on the differences of the monthly and the annual means, they will not be very much influenced by that error, but before combining the results of all the years, I had first considered separately the mean monthly discordances of the years 1868–74 (in the year 1875 a correction for wear is already added to the daily results). I found for those discordances the following values, to which I have added the mean discordances for the whole period, with their weights and their differences:—

Upper Culmination.

Month.	1868–74. Discordance.	Weight.	1851–82. Discordance.	Weight.	Diff.
	″		″		″
Jan.	+0·40	33·8	+0·37	161·6	+0·03
Feb.	+0·01	20·8	−0·07	113·6	+0·08
Mar.	−0·03	29·4	−0·21	146·6	+0·18
Apr.	−0·68	37·6	−0·51	155·4	−0·17
May	−0·44	35·5	−0·35	150·8	−0·09
June	−0·41	27·8	−0·35	122·6	−0·06
July	−0·41	10·7	+0·07	78·1	−0·48
Aug.	+0·40	6·8	+0·01	74·3	+0·39
Sept.	+0·05	41·7	+0·06	177·5	−0·01
Oct.	+0·12	57·7	+0·14	209·8	−0·02
Nov.	+0·26	44·8	+0·21	188·1	+0·05
Dec.	+0·48	42·6	+0·40	164·8	+0·08

Lower Culmination.

Month.	1868–74. Discordance.	Weight.	1851–82. Discordance.	Weight.	Diff.
	″		″		″
Jan.	+0·52	5·8	+0·20	45·9	+0·32
Feb.		0			
Mar.	+0·46	25·5	+0·27	133·1	+0·19
Apr.	+0·32	56·8	+0·20	235·1	+0·12
May	+0·13	67·3	+0·21	268·5	−0·08
June	−0·02	49·0	+0·08	213·4	−0·10
July	−0·41	52·2	−0·42	156·0	+0·01
Aug.	−0·64	33·0	−0·51	155·2	−0·13
Sept.	−0·35	37·5	−0·44	153·9	+0·09
Oct.	−0·23	37·6	−0·13	163·1	−0·10
Nov.	+0·26	34·8	+0·18	137·5	+0·08
Dec.	+0·51	30·5	+0·30	97·7	+0·21

From the differences of the discordances in the two periods, I found for the mean error of the unit of weight in both culminations the same value $\pm 0''\cdot67$. As the value of that mean error formerly found is $\pm 0''\cdot84$, there is no systematic difference, and I concluded that the wear of the screws had no appreciable influence on the discordances. I retained, therefore, the mean result of all the years.

I do not believe that the readings of the exterior and interior thermometer indicate exactly the temperature of the exterior air and of the object-glass, or rather of the ocular, as there is probably also a refraction in the tube; but as a correction, proportional to the differences of both thermometers, explains the greater part of the discordances, I think it probable that the mean

differences of both thermometers are proportional to the excess of temperature of the strata which cause the refraction in the observing-room.

Comparison of the Star-places of the Greenwich Ten-year Catalogue with those of the Second Melbourne General Catalogue, and with those of the Cape Catalogue for 1880. By A. M. W. Downing, M.A.

The epoch of the Greenwich Ten-year Catalogue and that of the Second Melbourne General Catalogue being the same (1880), the comparison between the places of the stars common to both—472 in number—is a very easy matter. The effect of a difference in the values of the assumed proper motions in any particular cases has been neglected in making the comparison, it being assumed that, in the mean, the effect of such differences would be inappreciable.

The following *errata* have been detected during the progress of the work:—

Greenwich, No. 1,627, *Lalande* 19,433,
for R.A. $9^h\ 49^m\ 11^s{\cdot}586$ *read* $9^h\ 49^m\ 12^s{\cdot}586$.
Melbourne, No. 735, γ *Hydræ*,
for R.A. $13^h\ 12^m\ 25^s{\cdot}02$ *read* $13^h\ 12^m\ 24^s{\cdot}02$.

Table I., given below, exhibits the differences Greenwich-Melbourne when the stars are arranged in order of N.P.D., and grouped as shown. Table II. gives the same differences when the stars are arranged in order of R.A., taken in groups of 1^h each.

TABLE I.

Extent of Group.	$\Delta\alpha$	$\Delta\delta$	No. of Stars in Group.
° °	s	"	
40–50	−·009	−0·56	22
50–60	−·009	−0·52	13
60–65	+·005	+0·31	24
65–70	+·003	+0·75	23
70–75	+·014	+0·96	14
75–80	+·001	+0·87	21
80–85	−·019	+0·68	27
85–90	−·017	+0·48	30
90–95	−·012	+0·62	42
95–100	−·003	+1·05	47
100–105	+·016	+1·30	67
105–110	+·042	+1·13	63
110–115	+·055	+1·34	42
115–120	+·071	+1·48	14
120–125	+·087	+2·05	23
40–125	+·015	+0·90	472

TABLE II.

Extent of Group.	$\Delta\alpha$	$\Delta\delta$	No. of Stars in Group.
h h	s	"	
0–1	+·021	+0·54	15
1–2	+·028	+1·29	17
2–3	+·053	+1·10	18
3–4	+·039	+0·68	22
4–5	−·001	+1·19	19
5–6	−·023	+0·61	26
6–7	−·003	+0·79	20
7–8	+·011	+0·98	21
8–9	+·008	+0·53	16
9–10	+·006	+1·09	18
10–11	+·025	+0·94	16
11–12	+·007	+0·72	16
12–13	+·015	+0·79	18
13–14	+·013	+0·90	16
14–15	+·004	+0·71	20
15–16	−·013	+0·34	15
16–17	+·022	+0·91	18
17–18	+·006	+0·73	17
18–19	−·001	+0·69	18
19–20	+·041	+0·72	21
20–21	+·013	+1·03	30
21–22	+·037	+1·05	19
22–23	+·028	+1·31	21
23–24	+·028	+1·44	35
0–24	+·015	+0·90	472

The following table gives the probable errors of a difference between the Catalogue places of a star, in R.A. and N.P.D. respectively, at different N.P.D.'s:—

TABLE III.

N.P.D.	ϵ_α	$\epsilon_\alpha \sin$ N.P.D.	ϵ_δ	No. of Stars in Group.
° °	s	s	"	
40–50	·036	·025	1·24	22
50–60	·044	·036	0·41	13
60–65	·024	·021	0·43	24
65–70	·024	·022	0·41	23
70–75	·030	·029	0·33	14
75–80	·016	·016	0·28	21
80–85	·028	·028	0·41	27
85–90	·025	·025	0·30	30
90–95	·033	·033	0·49	42
95–100	·037	·037	0·46	47
100–105	·043	·042	0·54	67
105–110	·041	·039	0·47	63
110–115	·040	·036	0·56	42
115–120	·042	·037	0·43	14
120–125	·055	·046	1·08	23

The mean value of $\epsilon_\alpha \sin$ N.P.D. is ^{s}·031, and that of ϵ_δ is 0″·52. Assuming that the places of stars in the two catalogues are equally affected by accidental errors, it follows that the mean probable errors of a R.A. and N.P.D. in either are $\pm$ ^{s}·022 cosec N.P.D. and $\pm$ 0″·37 respectively.

The differences exhibited in Tables I. and II. above, in R.A. and N.P.D. respectively, have been laid down as points on cross-ruled paper, and curves drawn through them, from which the differences corresponding to any R.A. or to any N.P.D. between the extreme limits can be read off. To each of the differences arranged in order of R.A. has been applied the mean difference (+^{s}·015 and +0″·90 in R.A. and N.P.D. respectively), with reversed sign, before entry in Table IV. below; so that the difference in either R.A. or N.P.D., corresponding to any position, is the sum of the quantities taken from Tables IV. and V. It is further to be remarked that the N.P.D.'s of the Second Melbourne General Catalogue, from N.P.D. 37° 50′ to 127° 50′, are corrected by the quantity −0″·149 + 0·00914 R, where R is the refraction of the *Tabulæ Regiomontanæ*. This was done "for the sake of uniformity," a similar correction having been applied to the N.P.D.'s of the First Melbourne General Catalogue, as the result of an examination of certain Melbourne observations. It appears, however, from a discussion published in *Monthly Notices*, vol. xli. pp. 346–357, that the conclusions previously arrived at on this point require considerable modification. Accordingly, in the comparison of the N.P.D.'s arranged

in order of N.P.D. in Table V. given below, whilst Column I. gives the comparison of Catalogue places as published, Column II. gives the comparison with the Melbourne places reduced with the refractions of the *Tabulæ Regiomontanæ*, and the corresponding correction applied to the value of the adopted latitude.

Column II. is, of course, the one that ought to be used in any discussion concerning the accuracy of the refractions adopted at Greenwich.

The differences Greenwich-Cape given below are derived from the values of Greenwich-Melbourne here given, combined with the values Melbourne-Cape published in *Monthly Notices*, vol. l. pp. 485, 486.

The comparatively large differences in R.A., in Table V., from N.P.D. 110° to 120°, and which are of the *same sign* in the comparisons of Greenwich with both Melbourne and the Cape, will be noticed.

TABLE IV.

R.A.	Greenwich-Melbourne.		Greenwich-Cape.	
h	s	"	s	"
0·0	+·010	+0·12	−·011	−0·13
1·0	+·012	+0·10	−·005	−0·10
2·0	+·024	+0·18	+·015	+0·04
3·0	+·023	+0·09	+·020	+0·08
4·0	+·006	+0·02	+·019	−0·02
5·0	−·018	−0·02	−·002	−0·22
6·0	−·025	−0·10	−·011	−0·25
7·0	−·015	−0·08	+·001	−0·12
8·0	−·006	−0·10	+·004	−0·15
9·0	−·005	−0·06	−·012	−0·09
10·0	−·001	+0·02	−·025	+0·10
11·0	·000	−0·06	−·042	+0·12
12·0	−·001	−0·10	−·042	+0·18
13·0	−·002	−0·08	−·034	+0·28
14·0	−·007	−0·14	−·039	+0·28
15·0	−·014	−0·28	−·038	+0·15
16·0	−·011	−0·26	−·021	+0·11
17·0	−·005	−0·14	−·005	+0·21
18·0	−·004	−0·12	+·008	+0·20
19·0	+·003	−0·12	+·013	+0·15
20·0	+·011	−0·04	+·026	+0·21
21·0	+·012	+0·12	+·045	+0·33
22·0	+·015	+0·30	+·043	+0·33
23·0	+·015	+0·32	+·005	+0·09

TABLE V.

N.P.D.	Greenwich-Melbourne.			Greenwich-Cape.	
		I.	II.		
°	s	"	"	s	"
50	−·009	−0·54	+1·71		
55	−·005	−0·50	+1·05	−·008	+0·09
60	·000	0·00	+1·15	−·004	+0·33
65	+·005	+0·53	+1·41	·000	+0·51
70	+·008	+0·88	+1·58	+·003	+0·53
75	+·004	+0·90	+1·45	+·002	+0·59
80	−·009	+0·76	+1·20	−·001	+0·59
85	−·016	+0·58	+0·92	−·005	+0·40
90	−·014	+0·56	+0·82	−·012	+0·17
95	−·007	+0·82	+1·01	−·011	+0·15
100	+·008	+1·20	+1·33	+·002	+0·35
105	+·027	+1·24	+1·32	+·014	+0·44
110	+·049	+1·24	+1·26	+·030	+0·54
115	+·065	+1·40	+1·37	+·054	+0·75
120	+·079	+1·77	+1·69	+·069	+1·14

Blackheath:
February 1891.

Note on the Parallax of β Aurigæ. By the Rev. Professor Pritchard, D.D., F.R.S.

Attention having been called to this star by the remarkable spectroscopic observations that have been made at Harvard and Potsdam, preparations were made for the early determination of the parallax. These observations necessarily come within the scheme for the determination of the relative parallax of the stars of the 2nd magnitude, in process of reduction at Oxford.

This star has been referred to two others, whose magnitudes are respectively 8 8 and 10·2 magnitude, and whose approximate co-ordinates are—

	Pos. Ang.	Distance.
	° ′	"
a	91 50	710·9
b	269 10	945·2

The resulting parallax from each of the stars is—

a	+0·065 ± 0·024
b	+0·059 ± 0·025

The identity of these relative parallaxes leads to the conclusion that the stars of comparison are either situated on a sphere

having *β Aurigæ* for its centre, or they belong to a remote system of stars in which *β Aurigæ* has no part, and this identity may possibly, therefore, indicate an absolute parallax.

Assuming the conclusions of Professor Vogel's determination of the distance between the centres of the two components of *β Aurigæ* at 1,650,000 geographical miles, it appears that the greatest angular separation of the two components is no more than 0″·005.

1891 *March* 12.

The Companions of Aldebaran. By S. W. Burnham.

I have recently finished a set of measures of the companions of *Aldebaran* with the large telescope, and these taken in connection with prior measures are of considerable interest in showing the relations existing between the bright star and its several attendants. The nearest companion was found with the Chicago 18½-inch refractor in 1877, and this is now shown to have the same proper motion as the principal star; a result which would not be expected considering the distance and great difference in magnitudes. Both distance and position angle appear to have remained unchanged, the small difference in measures being fully accounted for by the extreme minuteness of the companion and the difficulty of measuring it so near a first-magnitude star. It was a very difficult object to see with the Chicago telescope, and might easily be overlooked even with the 36-inch refractor. I give below all the measures that have been made of this star.

The more distant Herschel companion has been observed for more than a hundred years, and the change shown by the measures has usually been ascribed solely to the proper motion of *Aldebaran*. The distinguished French astronomer Flammarion was the first to notice the fact that the well-known proper motion of A could not account for the relative change, and therefore came to the conclusion that B must have a proper motion of its own, and in a different direction. Of the correctness of this view there can be no doubt, and the amount and direction of the relative displacement of C should be as well known as of most stars. This motion is almost exactly half that of A, and is perhaps larger than that of any known star as faint as the eleventh magnitude which is not connected and moving with some brighter component.

In looking at this object in 1888 with the 36-inch, I found that the Herschel companion was also double, or had a very faint attendant a little more than 2″ distant. This is too difficult for most telescopes, and I am not aware that it has been seen elsewhere. It was measured in 1888, and again this year.

The several positions of B and C, as shown by the measures,

are given accurately to scale on the diagram (Plate 4). The annual proper motion of A is taken as 0″·188 in the direction of 164°·4. The central position of A is for the date of Struve's measure of C (1836); and the later measures are laid off from the actual place of A along the line of its movement, as determined by the proper motion already given. In the same manner the positions of B are laid down, the first and last measures in each case being connected with A by the lines shown in the diagram.

The following are the measures used:—

A and B (β 550).

1877·89	109°·0	30″·45	β	3*n*
1878·00	110·5	31·26	Hl	3*n*
1880·11	111·2	31·46	β	2*n*
1888·82	109·5	30·90	β	2*n*
1890·87	109·0	31·34	β	3*n*

A and C (H VI. 66).

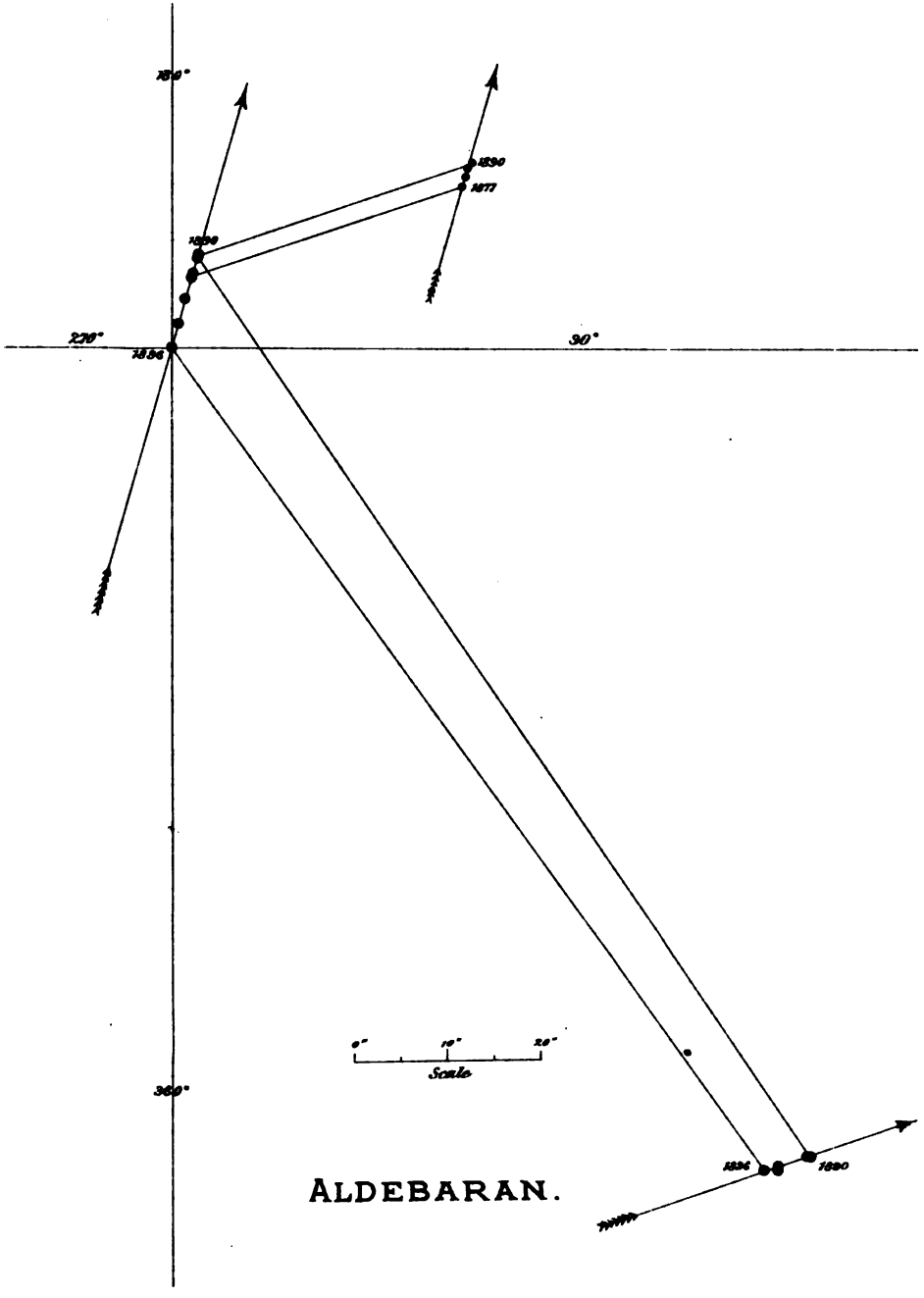
1836·06	36°·0	109″·04	Σ	2*n*
1851·40	35·5	111·60	OΣ	
1864·24	34·8	112·79	De	6*n*
1887·00	34·5	116·27	Hl	20*n*
1889·98	34·6	116·97	β	7*n*

C and D (β 1031).

1888·81	281°·1	2″·34	β	3*n*
1890·86	279·1	1·84	β	4*n*

It is apparent from the measures of B that its proper motion is substantially, and probably exactly, the same as that of A. The mean of the five sets of measures of this companion for the angle is 109°·8, and for the distance 31″·08. The differences between these values and the separate measures are really very small when the extreme faintness of the companion is taken into account.

From the measures of C we find that this companion has an annual motion of 0″·095 in the direction of about 109°·6. I have not used Herschel's measure of 1781, making the angle 36°·0, and the distance 87″·75. At best this would be only approximate. By the assumed motion of the stars, the angle at this time should have been 38°, and the distance 102″. Evidently at one time these stars were much nearer together; and by carrying the motions back it is shown that the minimum distance of 40″ occurred about A.D. 1130. At this time the



ALDEBARAN.

distance of BC was less than 11″; and about the middle of that century it was a little less than 9″.

The measures of CD do not cover a sufficient time to tell with certainty what the relation of D is to this group. As the angle of CD is nearly in the line of the motion of C, the distance between these stars should be about 0″·2 more in 1890 than in 1888, if D does not share the motion of C; but from the measures this distance is 0″·5 less at the former date. This would appear to indicate that the proper motion was common to both stars, and that there was a relative change due to some other cause. Measures made two or three years hence will at once settle this question.

The Herschel companion is the star generally used for the determination of the differential parallax of *Aldebaran*; but as the proper motion of the small star does not appear to have been taken into account, the result obtained would seem to be materially affected by an error from this source.

Mount Hamilton: 1890 *December* 25.

The Orbit of κ Pegasi (β 989). By S. W. Burnham.

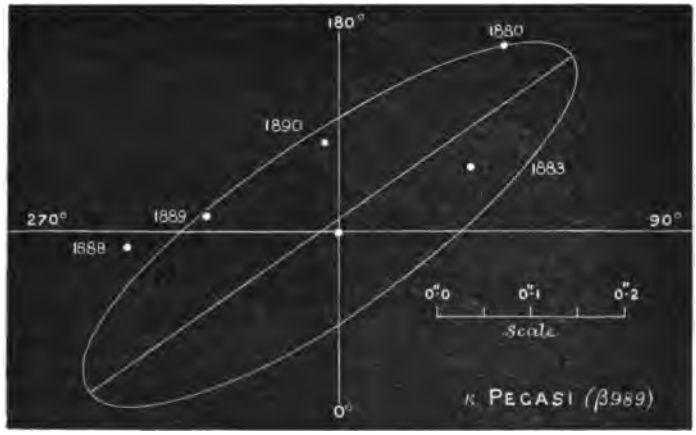
On August 12, 1880, while observing with the 18·5-inch refractor of the Dearborn Observatory, I came across the wide pair, *κ Pegasi*, and at once saw that the large star was a very close double. The measures made on this and following nights gave a distance of 0″·27, and this I thought was more likely to be too large than otherwise (*Monthly Notices*, xli. p. 33). I was unable to give any further attention to this star until the commencement of my measures made at the Lick Observatory, and the extreme difficulty of measuring so close a pair seems to have deterred other observers, with a single exception, from doing anything with it. The only record of any other observation of any kind is found in the work of the late Dr. Engelmann, of Leipzig. When we consider that his telescope had an aperture of only about 7·5 inches, it is almost wonderful that he could get even an approximate position, notwithstanding it was a Clark objective, and shows his great skill as an observer, and the superior defining qualities of his instrument. It is unfortunate that we have so little to represent the extraordinary motion of this pair in a few years through an angle of 230°. Since I have been at Mount Hamilton I have measured the close pair each year with the 36-inch refractor. During the measures of the past year it was extremely difficult, and was a severe test of the power of the great telescope with the very best atmospheric conditions. The highest powers were, of course, used, and it was necessary not only to exercise the utmost care in

focussing, but to keep the head in such a position that the line joining the eyes was parallel to the line of the two stars.

The following are the measures of the close pair :—

1880·68	137°·9	0″·27	β	4*n*
1883·02	116·0	0·16	En.	1*n*
1888·78	274·7	0·23	β	3*n*
1889·51	262·3	0·14	β	4*n*
1890·57	187·1	0·10	β	4*n*

It is plain from the few observations already made that we have a binary system in very rapid motion. It is too soon perhaps to expect from the data given anything more than a very approximate solution of the orbit by any method of investigation, but a graphical representation of the measures will at least give a general idea of the relation between the components.



I have laid down these measures with all possible accuracy on a large scale (1″=20 inches), and then drawn after repeated trials the apparent ellipse shown on the accompanying diagram. This ellipse satisfies the test of equal areas in equal times. The areas described by the radius vector between the position of 1880–89 and 1889–90 are exactly proportional to the times (1 : 8·33); and as the variation of these positions from the path described by the curve is far within the ordinary errors of observation in a much easier star than this, I think the figure may be taken as a fair approximation to the apparent motion of the components. According to this diagram, the distance at the time of Engelmann's measure was 0″·23, and the angle 113°; while for the position of 1888 the distance is 0″·21, and the position angle 281°. The other measures are substantially exact with reference to the assumed path of the secondary star. The

components differ in brightness by something less than one magnitude, and when they are separated by only a quarter of a second, the difference is not very plain. It might be suspected that the angle of 1880 should be increased 180°, or that the measures of the last three years should be diminished by that amount. Upon referring to the original observations, I find that I took special pains to give the proper quadrant at the time of discovery, as well as in the measures of 1888 and 1889; so that I feel every confidence in the accuracy of the observations in this respect.

If this figure correctly represents the relative motions, it is evident that the period is shorter than that of any known star in the heavens. It should make one revolution in a little more than eleven years, and by the time it is observable again during the present year it should have nearly completed one revolution, and have about the same angle and distance as at the time of discovery in 1880.

From the projected orbit we get the following :—

Major axis	0″·636
Minor axis	0″·187
Maximum distance	0″·32 (1881·7)
Minimum distance	0″·08 (1884·6)
Period	11·13 years
Position angle of major axis ...	125°·4

Apparently the real orbit is nearly circular, and makes an angle of about 75° with the line of sight. Whether the period of rotation is as short as that indicated, the motion is certainly very rapid, and the object one of the most interesting of its class. The measures which I hope to make during the coming summer will probably settle most of these questions. It should be comparatively easy to measure this year, as the distance will be not less than 0″·2.

This star has been known as a wide double star since the time of Sir William Herschel, who detected the companion, a star of ninth magnitude, in 1786. He described it as "extremely unequal, the small star almost north, but a little preceding." It was not measured until 1831, when Struve observed it, and incorporated it in his great catalogue as Σ2,824. The distance of the small star at that time was 11″. It has been frequently measured since, the distance now being a little more than 12″, with a very slow diminution of the position angle. An examination of these measures shows beyond all question that the apparent motion of the small star is rectilinear and uniform. The displacement during the interval between Struve's measures in 1831 and mine in 1888 amounts to 2″·08 in the direction of 252°.

This is undoubtedly the movement of the principal star, which has, therefore, an annual proper motion of 0″·036 in the direction of 72°.

On the Determination of Double Star Orbits from Spectroscopic Observations of the Velocity in the Line of Sight. By Arthur A. Rambaut, M.A.

(*Communicated by Sir. R. S. Ball.*)

I have shown in a paper which I read before the Royal Irish Academy in May 1886 how the relative velocity of the components of a double star is connected with the parallax and the elements of the orbit. In a later paper, published in the *Monthly Notices* of the Royal Astronomical Society for March 1890, I put the results in a more convenient form, and pointed out what velocities we might expect to find in the already known optical doubles.[1] The smallness of these velocities, however, seemed to show that, except perhaps in a very few cases, the spectroscopic observations of these stars were likely to prove extremely difficult.

At the time of writing the latter paper, although Professor Vogel had demonstrated the duplicity of *Algol*, and Professor Pickering the duplicity of *β Aurigæ* and *ζ Ursæ Majoris*, the results were so novel and startling that, although the idea occurred to me of solving the inverse problem—viz., to obtain the orbit from the spectroscopic observations alone—it did not seem to me that the observations were reliable enough to warrant the expenditure of the time which the solution of the question would require.

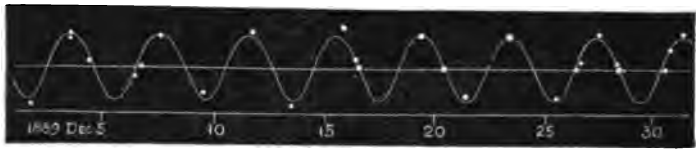
The beautiful results, however, obtained by Professor Pickering in the case of *β Aurigæ*, and published in the Fourth Annual Report of the Henry Draper Memorial, seem to throw a wholly new light on the question.

The frontispiece of this report contains five figures, the last four of which are reproductions of some of his photographic spectra, and exhibit the nature of the data on which his results depend. These prove at a glance that there is no question about the periodic displacement of the lines, and also show that the amount of the displacement is capable of measurement with very considerable accuracy.

It is, however, the first of these figures with which we are principally concerned at present. This is a curve in which the

[1] At the time of writing this I was not aware of a paper by Professor Niven in the *Monthly Notices* of the R.A.S., May 1874, dealing with the subject, in which he publishes formulæ almost identical with those given in the communications mentioned above.

time is taken as the abscissa and the relative velocity in the line of sight as ordinate. The portion of the curve given covers the whole of the month of December 1889, containing 27 measures of the displacement of the lines, and in no case does the actually



observed displacement differ from that derived from the curve by more than the accidental errors of measurement.

A glance at the curve shows that there is a periodic displacement occurring in about four days. To determine the period with greater accuracy it is necessary to take a series of observations extending over a long time, and to divide the interval which has elapsed by the number of periods which have occurred. For this purpose, of course, the longer the star is under observation, the more accurately can the period be determined. From the portion of the curve given in the report I find for the period:

$$P = 3{\cdot}968 \text{ days.}$$

We can now determine the form of the curve with greater accuracy. For if we take any arbitrary epoch as the zero of abscissæ and subtract once, twice, . . . n times P from the time, we can reduce all the observations within the same period, and thus obtain a very large number of points through which to draw the curve of velocities.

From Professor Pickering's report, treating the observations in the way just described, I obtain the following figures:—

t.	V.	t.	V.	t.	V.
0·48	−8·6	0·47	−8·6	0·74	0·0
0·94	+6·3	0·07	+8·8	0·79	+2·0
0·96	+7·6	0·20	+1·2	0·01	+8·0
0·17	+1·2	0·23	0·0	0·20	+1·4
0·67	−2·1	0·00	+7·7	0·22	0·0
0·76	0·0	0·24	0·0	0·26	−0·3
0·97	+7·1	0·48	−6·4	0·74	−0·3
0·46	−6·0	0·00	+7·8	0·81	+4·7
0·05	+8·3	0·50	−6·6	0·96	+8·0

In drawing the curve of velocities from these data there are two conditions which must be fulfilled, the reasons for which will appear when we come to determine the form of the orbit. *The*

first of these is that the area of the curve above the axis of t shall be equal to that below the same line; *the second*, that the area contained between the curve, the axis of t and the ordinate corresponding to maximum positive velocity, shall be equal to that contained between the curve, the axis of t, and the ordinate corresponding to maximum negative velocity.

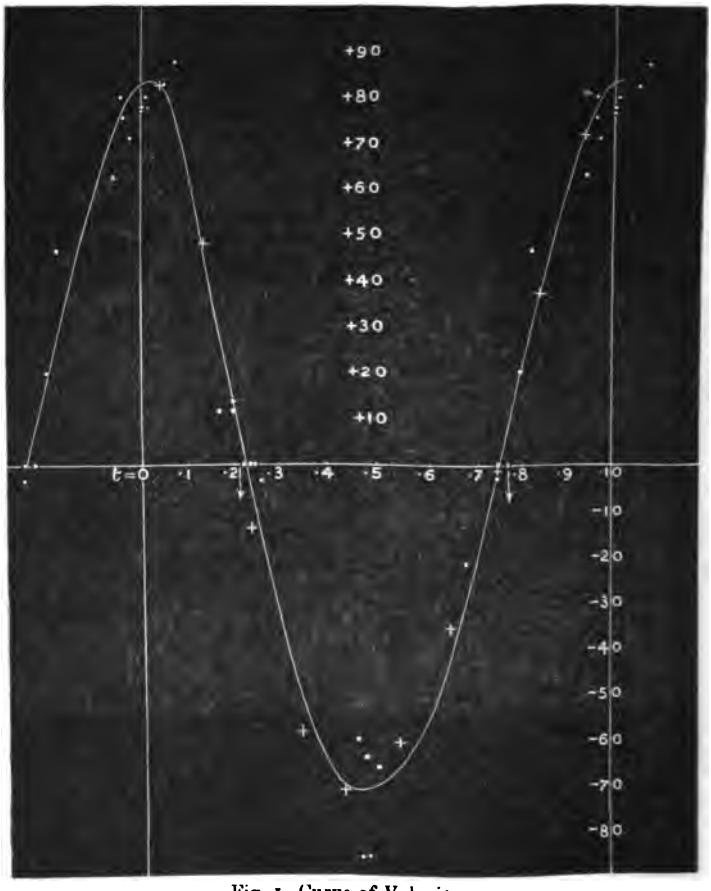


Fig. 1. Curve of Velocities.

With these two conditions in view, the curve shown in fig. 1 has been drawn from the figures given above.

I shall refer to it as *the curve of velocities*.

To Determine the Form of the Orbit.

If we take the line of sight as the axis of x, and the centre of the principal star as the origin of coordinates, we have, if V is

the relative velocity of the components in the line of sight, the equation

$$\frac{dx}{dt} = V,$$

and consequently

$$x = \int V dt \quad \ldots\ldots\ldots\ldots \quad (1)$$

The following considerations will enable us to determine the limits between which the integral is to be taken.

If we take the line of nodes as the axis of y, we have x equal to zero when the companion star is passing through this line. Now I have shown in my paper, already referred to, in the *Monthly Notices*, that when the companion is in this position the velocity in the line of sight is greatest. Hence it follows that if τ is the epoch corresponding to a maximum velocity, we have

$$x = \int_{\tau}^{t} V dt \quad \ldots\ldots\ldots\ldots \quad (2)$$

But when the companion is passing through the line of nodes on the other side of the primary, we have again $x=0$, and the velocity in the line of sight again a maximum, but in the opposite direction. Hence, if τ' is the epoch corresponding to this configuration, we have

$$0 = \int_{\tau}^{\tau'} V dt.$$

But the expression $\int_{\tau}^{\tau'} V dt$ is the area of the curve in fig. 1 between the greatest positive and the greatest negative ordinates; and since we see that this must be equal to zero, we obtain the second condition mentioned above for guidance in drawing our curve of velocities. Further, since the value of x is again zero at the line of nodes after a complete revolution has taken place, we see that we have

$$\int_{\tau'}^{\tau+P} V dt = 0;$$

or, what amounts to the same thing, the area of the curve of velocities, measured from the greatest negative to the greatest positive ordinate, is equal to zero. This, taken in connection with what we have already obtained, gives the first condition mentioned above, viz. that the area above the axis of t is equal to that below the same line.

In drawing this curve and computing the area contained between it and the axes, perhaps the most convenient method, and one which is quite sufficiently accurate for our present purpose, considering the nature of the data, is to plot down the observed

velocities on millimetre paper to any convenient scale, taking 100^{mm} to represent the whole period. We then take a sheet of ordinary ruled writing-paper and rule it with eleven equidistant lines, so as to divide it up into a number of spaces, as shown in the table given below. For every square centimetre in fig. 1, therefore, we have a corresponding space in the table, and if we enter in each of these spaces the number of square millimetres inclosed by the curve in the corresponding square on fig. 1, we have a register of the area of the curve in a very convenient form, which enables us to see where the shape of the curve is in error, and to correct it as may appear necessary, so as to fulfil the two conditions mentioned above, without the trouble of going back and recomputing the whole area of the curve at each alteration.

	0	1	2	3	4	5	6	7	8	9	10		
+90	16	...	...	...	...	...	...	...	...	4	20		
+80	74	...	...	...	...	...	...	...	...	47	121		
+70	98	3	...	...	...	...	...	...	...	84	186		
+60	100	20	...	...	...	...	...	...	14	100	234		
+50	100	38	...	...	...	...	...	...	42	100	280		
+40	100	58	...	...	...	...	...	...	68	100	326		
+30	100	77	...	...	...	...	...	1	93	100	371		
+20	100	95	1	...	...	...	...	17	100	100	413		
+10	100	100	27	...	...	...	...	40	100	100	467	2418	
0	...	...	63	100	100	100	100	37	...	...	500		
−10	...	...	41	100	100	100	100	10	...	...	451		
−20	...	...	21	100	100	100	86	...	...	...	407		
−30	...	...	3	98	100	100	58	...	...	...	359		
−40	...	...	...	76	100	100	27	...	...	...	303		
−50	...	...	...	47	100	94	2	...	...	...	243		
−60	...	...	...	9	94	46	...	...	...	...	149		
−70	...	...	...	...	6	...	...	...	...	...	6	2418	
−80	788	391	156	530	700	640	373	105	417	736	4836		

Hitherto we have only been concerned with the abscissæ, but in addition to the equation (1) we have the relation

$$x\frac{dy}{dt}-y\frac{dx}{dt}=c, \text{ a constant,}$$

which may be written in the form

$$y=cx\left[\mathrm{B}+\int\frac{dt}{x^2}\right] \quad \ldots\ldots\ldots\ldots (3)$$

This equation will enable us to determine y if we have any means of obtaining the values of the constants c and B.

In order to determine B it is necessary to refer to the equation

$$\pi\mathrm{V}=\frac{la\sin\gamma}{\mathrm{P}\sqrt{1-e^2}}\left[e\cos\lambda+\cos(\theta-\lambda)\right] \quad \ldots\ldots\ldots (4)$$

which I have obtained in my previous paper.

As I have pointed out there, if $\theta-\lambda=0$ or π, *i.e.* if the body is passing through the line of nodes, the velocity in the line of sight is a maximum. Let these two values of V be V_1 and V_2. We thus obtain

$$\frac{\pi}{2}(\mathrm{V}_1+\mathrm{V}_2)=\frac{la\sin\gamma}{\mathrm{P}\sqrt{1-e^2}}\cdot e\cos\lambda.$$

But when $y=0$ the line joining the two components—*i.e.* the radius vector—must be at right angles to the line of nodes, and consequently $\cos(\theta-\lambda)=0$. Hence, if V_3 is the velocity in the line of sight when in this position we have

$$\mathrm{V}_3=\tfrac{1}{2}(\mathrm{V}_1+\mathrm{V}_2),$$

or, *the ordinate* y *is zero at the moment when the velocity is a mean between the greatest positive and the greatest negative velocities.* Denoting this epoch, which we can determine from the curve of velocities, by the letter τ_0 we have

$$y=cx\int_{\tau_0}^{t}\frac{dt}{x^2} \quad \ldots\ldots\ldots\ldots (5)$$

We have not the means of determining from the spectroscopic observations what is the value of c, but if we take it to be any convenient factor, we shall obtain proportional values of y from equation (5), which, in connection with the values of x derived from equation (2), will enable us to construct an ellipse which is *an* orthographic projection of the real orbit on a plane passing through the line of nodes, although the angle between it and the real orbit is indeterminate.

Now this being an orthographic projection, the centre of the projected, is the projection of the centre of the real, ellipse, and the ratios of the various parts of the major axis of the real orbit are unaltered by projection. Consequently, if C (fig. 3) is the centre of the ellipse obtained as described above, P the primary,

which is also the origin of coordinates, and A and B the points in which the line CP meets the ellipse, we have

$$\frac{CP}{CA} = e \quad \ldots\ldots\ldots\ldots (6)$$

We have also from equation (4) the relations

$$V_1 = \frac{la \sin\gamma}{P\pi\sqrt{1-e^2}}(e\cos\lambda + 1), \text{ and } V_2 = \frac{la\sin\gamma}{P\pi\sqrt{1-e^2}}(e\cos\lambda - 1);$$

whence we obtain

$$e\cos\lambda = \frac{V_1 + V_2}{V_1 - V_2} \quad \ldots\ldots\ldots\ldots (7)$$

from which λ may be determined.

Again, if $\bar{a}$ represents the semi-major axis in miles, and R the radius of the earth's orbit, we have

$$\frac{\bar{a}}{R} = \frac{a}{\pi},$$

and equation (4) becomes

$$\frac{PRV\sqrt{1-e^2}}{l(e\cos\lambda + \cos(\theta - \lambda))} = \bar{a}\sin\gamma \quad \ldots\ldots\ldots (8)$$

from which $\bar{a}\sin\gamma$ may be determined, all the quantities on the left-hand side of the equation being already known. It will, however, be sufficient in general to take V_1 and V_2 from which to determine $\bar{a}\sin\gamma$. Thus we have

$$PRV_1\sqrt{1-e^2} = l\bar{a}\sin\gamma(e\cos\lambda + 1);$$

$$PRV_2\sqrt{1-e^2} = l\bar{a}\sin\gamma(e\cos\lambda - 1);$$

whence

$$\bar{a}\sin\gamma = \frac{PR\sqrt{1-e^2}}{2l}(V_1 - V_2) \quad \ldots\ldots\ldots (9)$$

There still remains one element which the data at our disposal enable us to determine. This is T, the epoch of periastron passage. We must, however, first determine the epoch of the passage through the node, which we shall call ϵ, and which may at once be read off the curve of velocities in fig. 1, being, in fact, the time of maximum velocity. Knowing the eccentricity we can then find the mean anomaly nt corresponding to the true anomaly λ. We have also got the mean motion equal to $\frac{2\pi}{P}$, whence we obtain

$$T = \epsilon \pm \frac{nt\,P}{2\pi} \quad \ldots\ldots\ldots\ldots (10)$$

In the case before us, from the velocities given above and the curve in fig. 1, which is drawn by means of them, we have the time of greatest velocity (*i.e.* ϵ) equal to $0{\cdot}02 \times P$ *later* than

the epoch which we have taken as the zero of abscissæ. The latter epoch is December 2·65, and since 0·02 × P = 0·08 days, we have

$$\epsilon = \text{Dec. } 2{\cdot}73.$$

Again, measuring the area of the curve from the ordinate corresponding to this epoch, we have the following values of

$$x, \frac{1000}{x}, \text{ and } \left(\frac{1000}{x}\right)^2 :-$$

t	x	$\frac{1000}{x}$	$\left(\frac{1000}{x}\right)^2$	t	x	$\frac{1000}{x}$	$\left(\frac{1000}{x}\right)^2$
0·06	+ 330	+ 3·030	+ 9·18	0·56	− 711	− 1·406	+ 1·98
·08	485	2·062	4·25	·58	833	1·200	1·44
·10	624	1·603	2·57	·60	945	1·058	1·12
·12	745	1·342	1·80	·62	1045	0·957	0·92
·14	845	1·183	1·40	·64	1131	0·884	0·78
·16	922	1·085	1·18	·66	1204	0·831	0·69
·18	979	1·021	1·04	·68	1264	0·791	0·63
·20	1015	0·985	0·97	·70	1310	0·763	0·58
·22	1032	0·969	0·94	·72	1340	0·746	0·56
·24	1030	0·971	0·94	·74	1354	0·739	0·55
·26	1008	0·992	0·98	·76	1352	0·740	0·55
·28	966	1·035	1·07	·78	1334	0·750	0·56
·30	905	1·105	1·22	·80	1297	0·771	0·59
·32	828	1·208	1·46	·82	1243	0·805	0·65
·34	735	1·361	1·85	·84	1173	0·853	0·73
·36	629	1·590	2·53	·86	1088	0·919	0·84
·38	511	1·957	3·83	·88	988	1·012	1·02
·40	+ 385	+ 2·597	+ 6·74	·90	874	1·144	1·31
				·92	748	1·337	1·79
0·50	− 310	− 3·226	+ 10·41	·94	− 608	− 1·645	+ 2·71
·52	448	2·232	4·98				
·54	582	1·718	2·95				

It will be noticed that the values of x from $t = 0{\cdot}40$ to $t = 0{\cdot}50$ and from $t = 0{\cdot}94$ to $t = 0{\cdot}06$ have been omitted from this table. This has been done in consequence of the fact that, x becoming very small, the corresponding values of $\frac{1000}{x}$ and $\left(\frac{1000}{x}\right)^2$ become too large to be manageable; in fact the curve in fig. 2 has a pair of infinite branches corresponding to these epochs.

The next step in the process is to plot down as ordinates the values of $\left(\frac{1000}{x}\right)^2$, which are given in the last column of this table, taking the corresponding values of t as abscissæ. We thus obtain the interpolating curve for

$$c\int_{\tau_0}^{t}\frac{dt}{x^2}$$

shown in fig. 2. To find the epoch τ_0 it is necessary to revert to fig. 1, and we find that $V_1=+84$ and $V_2=-71$, whence

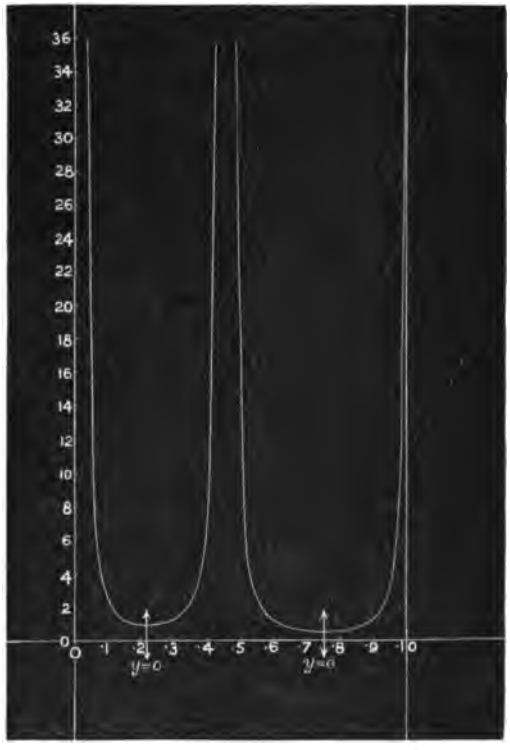


Fig. 2. Interpolating Curve for $c\int_{\tau_0}^{t}\frac{dt}{x^2}$.

$V_3=+6{\cdot}5$, and the epochs corresponding to this value of V are $t=0{\cdot}215$ and $t=0{\cdot}761$. These two epochs are marked in fig. 2 with double-headed arrows. Calculating the areas contained between these ordinates, and the ordinates corresponding to the epochs 0·02, 0·04, &c. we get the following values for

$$c\int_{\tau_0}^{t}\frac{dt}{x^2}.$$

t	$c\int_{\tau_0}^{t}\frac{dt}{x^3}$	t	$c\int_{\tau_0}^{t}\frac{dt}{x^3}$	t	$c\int_{\tau_0}^{t}\frac{dt}{x^3}$
0·06	−163	0·36	+ 92·5	0·72	− 8
·08	106	·38	123·5	·74	3
·10	76	·40	+173·5	·76	+ 2
·12	56			·78	7
·14	41	·50	−210	·80	12
·16	29	·52	138	·82	18
·18	18	·54	102	·84	25
·20	− 8	·56	79	·86	33
·22	+ 1	·58	63	·88	42
·24	10	·60	51	·90	53
·26	19·5	·62	41	·92	68·5
·28	29·5	·64	33	·94	+90
·30	40·5	·66	26		
·32	54	·68	19		
·34	+ 71	·70	− 13		

Since the value of c is perfectly arbitrary, we may for convenience divide these numbers by 100.

We thus obtain, by means of equation (5), the following corresponding values of x and y:—

t	x	y	t	x	y
0·06	+3·30	−5·38	·56	− 7·11	+ 5·62
·08	4·85	5·14	·58	8·33	5·25
·10	6·24	4·71	·60	9·45	4·82
·12	7·45	4·17	·62	10·45	4·28
·14	8·45	3·46	·64	11·31	3·73
·16	9·22	2·67	·66	12·04	3·12
·18	9·79	1·76	·68	12·64	2·40
·20	10·15	−0·81	·70	13·10	1·70
·22	10·32	+0·10	·72	13·40	1·07
·24	10·30	1·03	·74	13·54	+0·41
·26	10·08	1·97	·76	13·52	−0·27
·28	9·66	2·85	·78	13·34	0·93
·30	9·05	3·67	·80	12·97	1·56
·32	8·28	4·47	·82	12·43	2·23
·34	7·35	5·22	·84	11·73	2·92
·36	6·29	5·82	·86	10·88	3·60
·38	5·11	6·32	·88	9·88	4·15
·40	3·85	+6·68	·90	8·74	4·63
			·92	7·48	5·12
0·50	−3·10	+6·51	·94	− 6·08	−5·47
·52	4·48	6·18			
·54	5·82	5·94			

With these values of x and y the positions marked in fig. 3 have been plotted down, and the "apparent" ellipse drawn

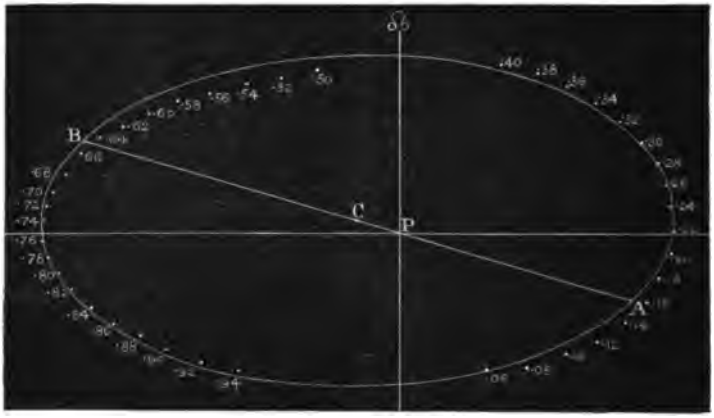


Fig. 3. "Apparent" Ellipse.

through them. Finding C the centre of this ellipse, and drawing CP to meet the curve in the point A, we have

$$\frac{CP}{CA} = 0{\cdot}156 = e$$

by equation (6).

We have also $V_1+V_2=13$ and $V_1-V_2=155$: hence by equation (7)

$$e \cos \lambda = \frac{13}{155} = 0{\cdot}0839.$$

and substituting the value just found for e, we find

$$\lambda = \pm 57°{\cdot}43.$$

In computing $\bar{a} \sin \gamma$, it must be remembered that the unit in terms of which we have expressed V hitherto is perfectly arbitrary. But when the displacements of the lines are expressed in wave-lengths we can at once convert the values of V into miles. In the Henry Draper Report the wave-lengths are not given, but Professor Pickering mentions that the greatest velocity amounts to 150 miles per second. This would make $\frac{1}{2}(V_1-V_2)=139{\cdot}5$ miles per second. Hence we obtain, by means of equation (9), —remembering that in that equation P is expressed in years, and that consequently we must put $\frac{3{\cdot}968}{365}$ for its value—

$$\bar{a} \sin \gamma = 0{\cdot}081 \times R.$$

If we assume R to be 93,000,000 miles, this corresponds to a distance of $7\frac{1}{2}$ millions. What the actual value of $\bar{a}$ may be the spectroscope does not enable us to determine, since in most

cases the value of γ will remain wholly indeterminate. In some special cases, however, such as that of *Algol*, where the variation of the lines synchronises with a variation in the brightness of the star, we may assume that γ is very nearly 90°, and that accordingly $\bar{a} \sin \gamma$ may be taken as the actual value of the semi-axis major.

We have still to compute the value of T. For this purpose we have the equation

$$\tan \tfrac{1}{2} u = \sqrt{\frac{1-e}{1+e}} \tan \tfrac{1}{2} \theta,$$

whence we obtain $u = 50°{\cdot}2$, when $\theta = \lambda$. Also the mean anomaly corresponding to this is $nt = 43°{\cdot}3$. Hence we obtain, by means of equation (10)

$$\begin{aligned} T &= \text{Dec. } 2{\cdot}65 + 0{\cdot}02 \,.\, P + 0{\cdot}12 \,.\, P. \\ &= \text{Dec. } 2{\cdot}65 + 0{\cdot}14 \,.\, P = \text{Dec. } 3{\cdot}21. \end{aligned}$$

We thus have the following elements of the orbit of *β Aurigæ* :—

$$P = 3{\cdot}968 \text{ days}; \qquad e = 0{\cdot}156;$$
$$T = 1889, \text{ Dec. } 3{\cdot}21; \qquad \lambda = 57°{\cdot}43;$$

and

$$\bar{a} \sin \gamma = 0{\cdot}081 \times R = 7{,}500{,}000 \text{ miles } \pm.$$

In order to test how far these elements will give results agreeing with the data from which they are derived, I have computed the velocity at intervals of a tenth of a period from the epoch of periastron passage. This occurs at $t = 0{\cdot}14$, as we have already seen.

I accordingly obtain the following table of results :—

t	V_c	V_o	t	V_c	V_o
0·04	+83·0	+83·0	0·54	−60·2	−65·7
·14	+48·2	+45·2	·64	−35·2	−40·0
·24	−14·2	− 7·0	·74	− 1·3	− 2·3
·34	−58·5	−51·0	·84	+37·7	+38·0
·44	−71·0	−70·5	·94	+72·1	+72·2

in which V_c denotes the computed velocity, and V_o that read from the curve in fig. 1. The points corresponding to the values of V_c are marked in fig. 1 by small crosses, from which it will be seen that on the whole they agree fairly well with the curve of velocities.

It will also be observed that the greatest discrepancies occur in what I have called the negative part of the curve. [I may,

however, remark in passing that positive and negative velocities are only relative terms in cases like the present, where the lines in the spectrum are of sensibly equal brightness, since the sign of the velocity will wholly depend on the choice we make between the lines as to which shall be considered as belonging to the primary and which to the satellite.] That these discrepancies should occur is hardly to be wondered at considering the scarcity of observations to guide us in drawing the curve in this region. In the positive part, where the observations are more numerous, the shape of the curve seems to have been hit off with very considerable accuracy, as the computed velocities lie very close to it indeed. A glance, also, will show that a very small alteration in the form of the negative portion of the curve would bring it into conformity with the computed points without doing much violence to any of the observed data, and I have no doubt that a curve might easily be drawn which would agree as well with the observed velocities as that shown in fig. 1, and at the same time give more consistent results. As, however, the velocities which I have used in constructing my curve are obtained by measuring the ordinates in Professor Pickering's report, and are, in consequence of the small scale on which his curve is given, affected with considerable errors, it does not appear advisable to push the calculation any further till the numerical results obtained by Professor Pickering are available. I have lately heard from Professor Pickering to the effect that the definitive measures upon the photographs of ζ *Ursæ Majoris* and β *Aurigæ* are in progress, and that he hopes before long to print their results with conclusions derived from them with regard to the orbits of the components of these stars. When these results appear I hope to be able to obtain more accurate values for the quantities P, T, e, λ, and $\bar{a}$ sin γ by the method pointed out above. In the meanwhile, perhaps, the results given in this preliminary notice, and the method of treating the question, may not be without value to those interested in the subject.

One point which my examination of the question seems to indicate very clearly is that the observations should be taken not so much at equal intervals of time, but as much as possible so that the points derived from them may lie equally thick along all parts of the curve of velocities, or, in other words, so that all parts of the curve may be determined with equal accuracy. In fig. 1 it will be seen that the majority of the observations are grouped about the positions of positive and negative maxima, whereas my results show that it is of equal importance to fix the exact time of the coincidence of the lines as well as the epoch at which the velocity is an arithmetic mean between its two extreme values.

I may remark, in conclusion, that in determining the orbit of stars of the *Algol* type, in which one of the components only is

bright enough to form a spectral image on the photographic plate, and in which consequently its displacement has to be determined by comparing it with an artificial line, the treatment of the observations will be somewhat different. In this respect, stars such as *Sirius*, for instance, will come under the same head, if we suppose the variations in their velocity in the line of sight to be due to orbital motion. In this class of star the *whole* velocity in the line of sight is measured, as Professor Vogel has done so skilfully in the case of *Algol*, and this is composed of two parts, viz: the orbital motion relative to the centre of gravity of the system, and the absolute motion of this point, the latter of which may be assumed to be constant in magnitude and direction.

If we have sufficient and accurate enough observations to determine the curve of velocities with certainty, it will be possible to separate the orbital motion of the brighter component from the absolute motion of the system by the first of the two conditions mentioned above on p. 318. For if we plot down the velocities as in fig. 1, the curve may or may not cut the axis of t, which represents the zero of total velocity, according as the orbital is greater or less than the absolute motion. But we have seen above that the line representing the zero of orbital velocity must cut the curve, so that the areas above and below it may be equal. Accordingly, if we draw a line parallel to the axis of t, to satisfy this condition, the distance of this line from the axis of t will represent the absolute motion of the system, and the distance from it to any point on the curve will represent the velocity due to the orbital motion in the corresponding position.

Although the materials are almost ludicrously inadequate to such an investigation, I have attempted to obtain some results from the six spectrographic observations of *Algol* published by Professor Vogel in the *Astronomische Nachrichten*, No. 2,947. I find that the motion of the centre of gravity is about $-0{\cdot}7$ or $-0{\cdot}8$ German geographical miles—Professor Vogel finds $-0{\cdot}5$ on the hypothesis of a circular orbit—and that the eccentricity is something between $\frac{1}{2}$ and $\frac{1}{3}$.

It must, however, be understood that these figures are but little better than mere guesses, on account of the paucity of observations, notwithstanding the great accuracy and value of those which are available.

January 7, 1891.

Additional Note.

When the lines are equal in brightness, as in the case of *β Aurigæ*, there is an ambiguity with regard to the sign of λ, and consequently, at first sight, with regard to the sign in equation (10),

since there are no means of determining whether the velocity is positive or negative in any given position: it is, in fact, positive for one component and negative for another, and there is no means of discriminating between the two. If, however, one of them is fainter than the other, we may confine our attention to the former, and we are then able to state that if the displacement is towards the red end of the spectrum the velocity is positive (*i.e.* the body is receding from us), and conversely.

In any case, however, the expression given for $e \cos \lambda$, given in equation (7), is positive if V_1 is greater than V_2. Consequently, if we take ϵ to be the time of passage through the node at which the velocity is greatest (which we may call ☊), λ will lie in the first or fourth quadrant, but there is no means of deciding, in the case of lines of equal brightness, which of these values for λ we are to choose. A positive value for λ with a rotation in one direction will give the same results as a negative value for λ with a rotation in the other direction. The question is, therefore, whether the motion is from periastron to ☊, or from ☊ to periastron. The following considerations will enable us to decide this point:—

The times of maximum velocity and the two epochs (τ_0), at which the velocity is a mean between its extreme values, mark four points on the orbit, the radii-vectores to which divide the orbit into four sectors, each of which contains a right angle. It is easy to prove that the periastron must fall in that sector whose area is least. We thus see that the time of periastron passage will fall in the shortest of the four intervals into which the period is divided by the four epochs, marked by the two maximum velocities and by the velocity which is a mean between its two maximum values. This shortest interval will always be either that immediately following or immediately preceding ϵ. In the former case we take the upper, in the latter we take the lower, sign in equation (10).

Double Star Measures at Windsor, New South Wales, 1889 *and* 1890. By John Tebbutt.

This communication contains the results of my double star measures during the years 1889 and 1890. The Grubb 8-inch equatoreal was employed throughout. The column headed "Hour-angles" gives the hour-angles between which the measures were made, and the last column the weights assigned from a consideration of the conditions under which the observations were made: 1 denotes an unusually bad condition and 5 an unusually good one. In the observations numbered 1, 6, 7, 24, 25 the components were estimated to be exactly equal. Observations 20 and 23 were made before sunset, and 2, 3, 4, 8, 13, 14, 21, 22, 29 in twilight. In observation 12 the driving-clock did not act well, and the measures were very inconsistent. The rapid angular motion of *Lalande* 4219, as indicated by the Washington, Leander McCormick, and Pinner observations, is not confirmed by the measures obtained here. The orbit of γ *Coronæ Australis* is at present far from being satisfactorily determined. Mr. Powell, in his paper published in the *Monthly Notices* for March last, states that the Windsor measures of distance are considerably greater than they should be. A practised observer will, however, be satisfied, by a mere glance at the components, that the distance is much greater than that shown by Mr. Powell's orbit. Mr. Burnham, in *Astron. Nachr.* Band 124, p. 74, gives the distance for 1889·41 as $1''{\cdot}79$. The following errata occur in my Double Star Results in the *Monthly Notices* for November 1889:—Page 25, *for* Lac. 5147 *read* a' Crucis and Lac. 5147; page 26, *for* 1888·320 *read* 1888·326.

Double Star Measures at Windsor, New South Wales, 1889 and 1890.

No.	Star.	Observed Magnitude.	Approx. Place of Star. R.A. h m	Dec. S. ° ′	Date of Obs.	Position-angle. °	No. of Obs.	Distance. ″	No. of Obs.	Mag. Power.	Hour-angles. h m	h m	Weight.
1	*p* Eridani	6, 6	1 36	56 45	1889·852	226·8	10	...	...	230	1 42 E	1 30 E	4
2	„	...	„	„	1889·882	226·6	10	...	...	230	2 38 E	2 30 E	4
3	„	...	„	„	1889·884	...	...	7·07	10	230	2 50 E	2 36 E	4
4	„	...	„	„	1889·884	227·5	10	...	...	230	2 36 E	2 26 E	4
5	„	...	„	„	1889·904	...	...	6·92	10	170	2 10 E	1 54 E	4
6	„	...	„	„	1890·819	...	...	7·15	10	170	2 21 E	2 6 E	4
7	„	...	„	„	1890·819	226 9	10	...	...	300	2 6 E	1 40 E	4
8	„	...	„	„	1890·832	227·4	10	...	...	300	4 14 E	4 3 E	4
9	Lalande, 4219	8½, 9	2 11	18 44	1890·857	...	...	1·86	10	170	1 14 E	0 53 E	3
10	„	...	„	„	1890·857	343·2	10	...	...	230	0 19 E	0 6 W	2
11	„	8, 8½	„	„	1890 923	344·8	10	...	...	230	1 3 E	0 36 E	3
12	„	...	„	„	1890·980	339·6	10	...	...	230	1 22 W	1 56 W	2
13	γ Centauri	...	12 35	48 21	1890·361	358·9	10	...	...	300	4 7 E	3 42 E	4
14	„	...	„	„	1890·361	359·0	10	1·84	8	500			
15	*h* 4634	9, 10	13 50	55 30	1890·359	17·6	10	12·87	7	140	2 11 E	1 43 E	4
16	α Centauri	...	14 32	60 23	1890·359	...	...	18·75	7	140	2 21 E	1 43 E	4
17	„	...	„	„	1890·359	205·2	10	...	...	230			
18	„	...	„	„	1890·463	...	...	18·42	10	130	1 23 E	0 59 E	3
19	„	...	„	„	1890·463	205·2	10	...	...	140	0 59 E	0 29 E	3

No.	Star.	Observed Magnitude.	Approx. Place of Star. R.A.	Dec. S.	Date of Obs.	Position-angle.	No. of Obs.	Distance.	No. of Obs.	Mag. Power.	Hour-angles.		Weight.
			h m	° ′		°		″			h m	h m	
20	α Centauri	...	14 32	60 23	1890·734	...	...	18·60	10	170	3 15 W	3 30 W	3
21	,,	...	,,	,,	1890·734	204·6	10	...	...	300	3 40 W	3 49 W	3
22	,,	...	,,	,,	1890·734	...	...	18·77	10	300	3 59 W	4 12 W	3
23	,,	...	,,	,,	1890·750	...	...	18·71	10	...	3 32 W	3 50 W	3
24	Brisb. 5784	9, 9	16 33	60 43	1890·734	116·6	10	...	...	230	3 52 W	4 15 W	4
25	,,	...	,,	,,	1890·734	...	...	3·50	10	170	4 27 W	4 43 W	4
26	Brisb. 6556	...	18 54	37 13	1889·849	282·7	8	...	...	140	4 18 W	4 44 W	4
27	γ Cor. Aust.	...	18 59	37 13	1889·813	...	...	2·30	10	130	...	...	3
28	,,	...	,,	,,	1889 835	184·5	10	...	...	140	3 15 W	3 28 W	4
29	,,	...	,,	,,	1889·838	185 4	10	...	...	230	...	2 38 W	4
30	,,	6, 6	,,	,,	1889·849	186·9	10	...	...	230	2 51 W	3 1 W	4
31	,,	...	,,	,,	1889·849	185·0	10	...	...	140	4 18 W	4 44 W	4
32	,,	...	,,	,,	1890·531	182·8	10	...	...	300	3 33 E	3 16 E	3
33	,,	...	,,	,,	1890·531	...	...	1·62	5	300	3 16 E	3 2 E	3
34	,,	...	,,	,,	1890·534	182·8	10	...	...	300	2 27 E	2 14 E	3
35	,,	...	,,	,,	1890·550	185·6	10	...	...	300	3 9 E	2 51 E	3
36	,,	...	,,	,,	1890·550	...	...	1·63	10	170	2 20 E	2 6 E	4
37	,,	...	,,	,,	1890·600	...	...	1·64	10	170	2 12 E	2 0 E	3
38	,,	...	,,	,,	1890·709	180·7	10	...	...	170	2 12 W	2 28 W	...
39	,,	...	,,	,,	1890·709	...	...	1·54	10	...	2 39 W	3 1 W	...

Private Observatory, Windsor, New South Wales:
1891 *January* 16.

Observations of the Variable Star S. (10) Sagittæ. By J. E. Gore.

The following are my observations of this short-period variable during the year 1890. They form a continuation of the observations given in *Monthly Notices* for March 1890.

The comparison stars are as before :—

	Mag.
11 Sagittæ	5·8
D M + 16°, 4086	7·0

Date.	Dublin M.T. h	m	Mag.
1890, Jan. 8	6	6	6·24
13	5	55	5·8
May 14	10	18	6·34
18	10	30	6·0
26	10	35	5·65
July 10	10	50	6·2
16	10	37	6·0
27	9	50	6·34
30	9	55	6·3
Aug. 5	10	35	6·16
6	9	20	6·4
7	9	25	6·48
8	10	15	6·2
9	9	20	6·1
11	10	25	5·8
15	9	0	6·37
16	10	15	6·2
17	9	12	6·0
25	9	20	6·0
28	9	10	5·8
29	9	0	5·95
30	9	10	6·1

Date.	Dublin M.T. h	m	Mag.
1890, Sept. 4	8	30 (?)	5·8
6	8	20	6·0
6	10	25	5·95
7	8	40	6·1
8	8	28	6·24
9	9	10	6·34
12	8	42	5·95
15	9	40	6·12
18	8	15	6·24
22	10	0	5·8
27	10	14	6·23
28	7	15	6·2
Oct. 7	7	20	5·8
8	6	45	5·65
12	9	10	6·34
17	8	20	5·8
Nov. 7	6	50	6·28
8	10	15	6·04
11	8	15	5·8
12	7	58	5·73
15	6	25	6·33
Dec. 4	5	40	6·08
29	6	30	6·13

Note on the Orbit of Juno. By A. M. W. Downing, M.A.

The following comparison of the observations of *Juno* made with the Transit Circle of the Royal Observatory, Greenwich, near the time of opposition in 1890, with (i.) the tabular places of the *Nautical Almanac*, and (ii.) with an ephemeris computed from the elements published in *Monthly Notices*, vol. l. p. 495, which the Astronomer Royal kindly permits me to publish, may be of interest.

Day, 1890.	Error of Tabular R.A.		Error of Tabular N.P.D.	
	I.	II.	I.	II.
	s	s	″	″
May 5	−4·08	+0·21	−5·64	+0·86
12	−3·99	+0·37	−7·08	−0·48
20	−4·24	+0·17	−6·01	+0·59
21	−4·31	+0·11	−5·82	−0·78
26	−4·39	+0·04	−5·05	−1·55
30	−4·28	+0·14	−5·62	+0·88
June 4	−4·40	+0·01	−8·19	−1·79
6	−4·49	−0·09	−4·71	+1·69
Mean ...	−4·27	+0·12	−6·02	−0·07

Blackheath:
March 1891.

Observations of the Planet Victoria and Comparison Stars made with the Transit Circle of the Radcliffe Observatory, Oxford, during the Opposition of 1889.

(*Communicated by E. J. Stone, M.A., F.R.S., Radcliffe Observer.*)

Observations of the Planet Victoria.

[The N.P.D.'s are corrected for Refraction but not for Parallax.]

Greenwich Mean Time of Observation. 1889.	Observer.	Observed Magnitude.	R.A. Apparent Places.	N.P.D.	Observer's Remarks.
			h m s	° ′ ″	
June 25 13 46 42·4	F.B.	...	19 59 11·31	96 38 55·14	Very faint, hazy.
26 13 42 15·2	R.	9–8	19 58 39·91	96 31 24·23	
July 5 13 1 1·8	R.	8–9	19 52 48·77	95 33 35·32	
10 12 37 28·5	R.	8	19 48 54·37	95 9 59·63	Good.
18 11 59 21·1	F.B.	...	19 42 13·19	94 45 47·68	Very faint, bad definition; observed in dark field.
23 11 35 33·6	R.	8–9	19 38 4·55	94 39 23·76	
27 11 16 42·9	F.B.	...	19 34 56·99	94 38 51·48	Very faint, diffused.
29 11 7 23·6	W.	...	19 33 29·26	94 40 6·33	
Aug. 3 10 44 28·2	F.B.	...	19 30 12·90	94 47 0·87	
5 10 35 28·9	F.B.	8–9	19 29 5·24	94 51 11·99	
6 10 31 1·7	R.	...	19 28 33·82	94 53 34·07	
15 9 52 23·1	F.B.	9	19 25 17·87	95 21 46·48	Faint.
17 9 44 10·3	F.B.	9–10	19 24 56·84	95 29 24·01	Faint; observed in dark field.
29 8 57 56·9	F.B.	10–9	19 25 54·51	96 20 49·87	

Comparison Stars observed with Victoria. Separate Results.

Day.	Observer.	Obs. Mag.	Mean R.A. 1889 Jan. 1.	Mean N.P.D. 1889 Jan. 1.	Notes.
			Schön. Z. −6°, No. 5151.		
			h m s	° ′ ″	
June 25	F. B.		19 21 25·26	95 57 20·65	
July 15	R.		25·16	21·26	
19	R.		25·16	21·95	
			19 21 25·19	95 57 21·29	
			Schön. Z. −6°, No. 5158.		
June 26	R.	9–8	19 23 2·45	96 24 0·62	
July 10	R.	9–8	2·58	2·53	
18	F. B.	8–9	2·38	0·76	
		9–8	19 23 2·47	96 24 1·30	
			Schön. Z. −5°, No. 4985.		
July 5	R.	9–8	19 24 6·10	95 9 5·53	
Aug. 3	F. B.		6·24	6·23	
5	F. B.	9–8	6·35	6·31	
		9-8	19 24 6·23	95 9 6·02	
			Schön. Z. −5°, No. 4989.		
July 23	R.	9–8	19 25 17·97	95 54 13·46	
Aug. 30	W.		17·89	12·62	
Sept. 18	F. B.	8–9	17·86	13·62	
		9–8	19 25 17·91	95 54 13·23	
			Schön. Z. −5°, No. 4992.		
July 29	W.		19 25 40·35	95 21 4·31	
Sept. 10	R.		40·26	2·79	
25	R.		40·26	1·50	Very faint and bad image.
			19 25 40·29	95 21 2·87	
			Schön. Z. −5°, No. 5006.		
June 25	F. B.		19 27 50·39	94 58 48·47	
July 15	R.		50·47	49·39	
27	F. B.	8–7	50·43	48·86	
		8–7	19 27 50·43	94 58 48·91	

Day.	Observer.	Obs. Mag.	Mean R.A. 1889 Jan. 1.	Mean N.P.D. 1889 Jan. 1.	Notes.
			Schön. Z. −4°, No. 4843.		
			h m s	° ′ ″	
July 10	R.	9–8	19 28 37·63	94 41 24·21	
Aug. 26	F. B.		37·55	22·15	
Sept. 17	R.	9–8	37·63	22·63	
		9–8	19 28 37·60	94 41 23·00	
			Schön. Z. −4°, No. 4846.		
June 26	R.	8–9	19 29 20·73	94 33 5·45	
July 5	R.	8	20·74	5·23	
8	R.		20·73	6·33	
		8	19 29 20·73	94 33 5·67	
			Schön. Z. −5°, No. 5021.		
Aug. 30	W.		19 30 41·15	95 1 3·89	A fainter star (Schön. Z. −5°, 5020) precedes about 15°, and is 2 south.
Sept. 10	R.		41·13	3·48	
18	F. B.	8–7	41·15	2·81	
		8–7	19 30 41·14	95 1 3·39	
			Schön. Z. −4°, No. 4855.		
June 26	R.	8–7	19 30 53·38	94 32 43·63	
July 5	R.	8–7	53·25	43·09	
Sept. 13	R.		53·37	43·74	
		8–7	19 30 53·33	94 32 43·49	
			Schön. Z. −3°, No. 4649.		
Aug. 15	F. B.	8	19 31 22·12	93 43 19·57	
17	F. B.		22·21	18·24	
Sept. 25	R.		22·15	19·74	
		8	19 31 22·16	93 43 19·18	
			Schön. Z. −4°, No. 4861.		
Aug. 31	F. B.		19 31 53·88	94 53 40·34	
Sept. 9	W.		53·88	40·61	
Oct. 9	F. B.	5–6	53·98	41·46	
		5–6	19 31 53·91	94 53 40·80	
			Schön. Z. −5°, No. 5036.		
July 18	F. B.	7–6	19 34 26·79	95 42 7·40	
Aug. 26	F. B.		26·70	7·11	Bad definition.
29	F. B.	7	26·84	7·36	
		7–6	19 34 26·78	95 42 7·29	

Day.	Observer.	Obs. Mag.	Mean R.A. 1889 Jan. 1.	Mean N.P.D. 1889 Jan. 1.	Notes.
			Schön. Z. −4°, No. 4877.		
			h m s	° ′ ″	
Aug. 7	F. B.	8–7	19 34 53·52	94 17 21·28	
15	F. B.	8–7	53·35	20·84	
17	F. B.		53·55	21·14	
		8–7	19 34 53·47	94 17 21·09	
			Schön. Z. −4°, No. 4883.		
June 26	R.	8	19 35 56·00	94 32 49·36	
July 5	R.	8–7	55·88	48·91	Elongated image.
8	R.		56·10	49·64	
Sept. 13	R.		...	49·97	
		8–7	19 35 55·99	94 32 49·47	
			Schön. Z. −4°, No. 4903.		
June 25	F. B.		19 39 23·65	94 47 23·08	
26	R.	9	23·66	22·52	
Aug. 5	F. B.	8	23·68	22·18	
		8–9	19 39 23·66	94 47 22·59	
			Schön. Z. −4°, No. 4916.		
July 8	R.		19 40 59·42	93 55 61·36	
29	W.		59·47	61·71	
Aug. 15	F. B.	7–8	59·48	...	
Oct. 9	F. B.	7–8	59·53	59·87	
		7–8	19 40 59·48	93 55 60·98	
			Schön. Z. −5°, No. 5060.		
July 10	R.	8	19 41 53·34	95 30 24·25	
27	F. B.		53·22	23·05	
Aug. 7	F. B.	8–7	53·35	23·22	
		8	19 41 53·30	95 30 23·51	
			Schön. Z. −4°, No. 4926.		
June 25	F. B.		19 43 4·47	94 46 19·23	
26	R.	8–9	4·43	18·50	Mag. 8–7 on Aug. 5.
July 5	R.	8–7	4·40	17·39	Mag. 8 on Aug. 29.
18	F. B.		4·53	17·12	Mag. 8–7 on Sept. 18.
		8	19 43 4·46	94 46 18·06	

Day.	Observer.	Obs. Mag.	Mean R.A. 1889 Jan. 1.	Mean N.P.D. 1889 Jan. 1.	Notes.
			Schön. Z. −4°, No. 4936.		
			h m s	° ′ ″	
June 26	R.	8	19 43 43·78	94 48 24·77	
July 5	R.	8–7	43·76	24·82	Mag. 8 on Aug. 29.
Aug. 5	F. B.	8–7	43·87	26·33	Mag. 8 on Sept. 18.
		8	19 43 43·80	94 48 25·31	
			Schön. Z. −5°, No. 5075.		
July 29	W.		19 44 56·09	94 58 28·56	Mag. 7 on Aug. 29.
Aug. 3	F. B.		56·24	28·20	Mag. 7–6 on Sept. 18.
6	R.		56·21	27·91	
		7–6	19 44 56·18	94 58 28·22	
			Schön. Z. −4°, No. 4960.		
July 23	R.	8	19 47 27·23	94 51 32·04	
Aug. 17	F. B.	8–7	27·17	31·80	
29	F. B.	8–9	27·17	33·01	Mag. 8–7 on Aug. 5.
		8	19 47 27·19	94 51 32·28	
			Schön. Z. −5°, No. 5099.		
June 25	F. B.		19 48 22·31	95 20 0·36	
Aug. 28	W.		22·42	0·20	Mag. 8–7 on Aug. 5.
30	W.		22·35	1·75	
		8–7	19 48 22·36	95 20 0·77	
			Schön. Z. −5°, No. 5120.		
June 26	R.	8–9	19 51 25·88	94 58 53·84	
July 29	W.		25·90	55·68	Mag. 8–9 on Aug. 5.
Aug. 15	F. B.	8–9	25·80	54·66	
		8–9	19 51 25·86	94 58 54·73	
			Schön. Z. −5°, No. 5124.		
July 5	R.		19 52 3·41	95 28 59·19	Only one bisection in N.P.D.
Aug. 7	F. B.	9–8	3·52	59·51	
Sept. 6	R.		3·52	60·03	
		9–8	19 52 3·48	95 28 59·58	
			Schön. Z. −6°, No. 5320.		
Aug. 6	R.		19 52 18·09	96 38 56·74	
26	W.		18·10	54·86	
Sept. 10	R.		18·11	56·52	
			19 52 18·10	96 38 56·04	

Day.	Observer.	Obs. Mag.	Mean R.A. 1889 Jan. 1.	Mean N.P.D. 1889 Jan. 1.	Notes.
			Schön. Z. −4°, No. 4984.		
			h m s	° ′ ″	
July 23	R	8	19 52 37·97	94 39 16·66	A fainter star (Sch. Z −4°,4982) precedes 18ˢ, and of same N.P.D.
Aug. 17	F. B.	8	37·95	15·75	
Sept. 12	W.		38·04	16·83	Mag. 8–9 on Oct. 9.
		8	19 52 37·99	94 39 16·41	
			Schön. Z. −4°, No. 4992.		
July 10	R.	7–8	19 54 57·29	94 36 53·46	
Aug. 28	W.		57·28	52·37	
29	F. B.	7–8	57·34	53·02	
		7–8	19 54 57·30	94 36 52·95	
			Schön. Z. −6°, No. 5339.		
July 29	W.		19 55 39·76	96 40 50·54	
Aug. 30	W.		39·73	50·21	
Sept. 18	W.	8–9	39·79	49·18	
		8–9	19 55 39·76	96 40 49·98	
			Schön. Z. −5°, No. 5138.		
July 18	F. B.		19 56 17·67	95 17 47·82	Bad image.
27	F. B.	7–6	17·59	48·90	
Aug. 3	F. B.		17·62	49·20	
		7–6	19 56 17·63	95 17 48·64	
			Schön. Z. −8°, No. 5205.		
Aug. 7	F. B.	8–9	19 57 4·80	98 0 13·93	
Sept. 10	R.		4·82	15·77	
Oct. 12	R.		4·71	14·18	
		8–9	19 57 4·78	98 0 14·63	
			Schön. Z. −5°, No. 5144.		
Aug. 15	F. B.	8–9	19 57 21·65	94 56 28·48	
Sept. 6	R.		21·78	28·56	
		8–9	19 57 21·72	94 56 28·52	
			Schön. Z. −6°, No. 5360.		
July 23	R.	8–9	19 59 23·73	96 53 57·87	
Aug. 6	R.		23·78	58·06	
17	F. B.	8–9	23·71	56·37	
		8–9	19 59 23·74	96 53 57·43	

Day.	Observer.	Obs. Mag.	Mean R.A. 1889 Jan. 1.	Mean N.P.D. 1889 Jan. 1.	Notes.
			Schön. Z. −4°, No. 5016.		
			h m s	° ′ ″	
July 18.	F. B.		20 0 44·77	94 44 3·35	
Aug. 30	W.		44·86	5·38	
Sept. 12	W.		44·77	3·81	
			20 0 44·80	94 44 4·18	
			Schön. Z. −7°, No. 5169.		
July 10	R.	7–8	20 0 46·73	97 19 57·08	
Aug. 7	F. B.	8	46·67	55·17	
28	W.		46·66	55·50	
29	F. B.	8	46·62	56·69	
		8–7	20 0 46·67	97 19 56·11	
			Schön. Z. −8°, No. 5237.		
July 29	W.		20 1 3·61	98 29 60·00	
Aug. 3	F. B.		3·65	59·62	
Sept. 13	R.		3·62	60·11	
			20 1 3·63	98 29 59·91	
			Schön. Z. −7°, No. 5183.		
June 26	R.	8	20 2 45·79	97 20 33·28	Mag. 8–7 on Aug. 15.
July 10	R.	7–8	45·73	34·38	Mag. 8–7 on Aug. 29.
		8–7	20 2 45·76	97 20 33·83	
			Schön. Z. −9°, No. 5382.		
July 5	R.	6–7	20 5 8·88	99 10 12·15	
23	R.	7–6	8·92	13·08	Mag. 6–7 on Aug. 15.
27	F. B.	6 7	8·75	12·50	
		6–7	20 5 8·85	99 10 12·58	

Mean Places of Comparison Stars observed with Victoria.

Star's Name.	Observed Mag.	Mean R.A. 1889, Jan. 1.	No. of Obs. in R.A.	Mean N.P.D. 1889 Jan. 1.	No. of Obs. in N.P.D.
		h m s		° ′ ″	
Schön Z. −6°·5151	...	19 21 25·19	3	95 57 21·29	3
−6·5158	9–8	19 23 2·47	3	96 24 1·30	3
−5·4985	9–8	19 24 6·23	3	95 9 6·02	3
−5·4989	9–8	19 25 17·91	3	95 54 13·23	3
−5·4992	...	19 25 40·29	3	95 21 2·87	3
−5·5006	8–7	19 27 50·43	3	94 58 48·91	3
−4·4843	9–8	19 28 37·60	3	94 41 23·00	3

Star's Name.	Observed Mag.	Mean R.A. 1889 Jan. 1.	No. of Obs. in R.A.	Mean N.P.D. 1889 Jan. 1.	No. of Obs. in N.P.D.
		h m s		° ′ ″	
Schön Z. −4·4846	8	19 29 20·73	3	94 33 5·67	3
−5·5021	8–7	19 30 41·14	3	95 1 3·39	3
−4·4855	8–7	19 30 53·33	3	94 32 43·49	3
−3·4649	8	19 31 22·16	3	93 43 19·18	3
−4·4861	5–6	19 31 53·91	3	94 53 40·80	3
−5·5036	7–6	19 34 26·78	3	95 42 7·29	3
−4·4877	8–7	19 34 53·47	3	94 17 21·09	3
−4·4883	8–7	19 35 55·99	3	94 32 49·47	4
−4·4903	8–9	19 39 23·66	3	94 47 22·59	3
−4·4916	7–8	19 40 59·48	4	93 56 0·98	3
−5·5060	8	19 41 53·30	3	95 30 23·51	3
−4·4926	8	19 43 4·46	4	94 46 18·06	4
−4·4936	8	19 43 43·80	3	94 48 25·31	3
−5·5075	7–6	19 44 56·18	3	94 58 28·22	3
−4·4960	8	19 47 27·19	3	94 51 32·28	3
−5·5099	8–7	19 48 22·36	3	95 20 0·77	3
−5·5120	8–9	19 51 25·86	3	94 58 54·73	3
−5·5124	9–8	19 52 3·48	3	95 28 59·58	3
−6·5320	...	19 52 18·10	3	96 38 56·04	3
−4·4984	8	19 52 37·99	3	94 39 16·41	3
−4·4992	7–8	19 54 57·30	3	94 36 52·95	3
−6·5339	8–9	19 55 39·76	3	96 40 49·98	3
−5·5138	7–6	19 56 17·63	3	95 17 48·64	3
−8·5205	8–9	19 57 4·78	3	98 0 14·63	3
−5·5144	8–9	19 57 21·72	2	94 56 28·52	2
−6·5360	8–9	19 59 23·74	3	96 53 57·43	3
−4·5016	...	20 0 44·80	3	94 44 4·18	3
−7·5169	8–7	20 0 46·67	4	97 19 56·11	4
−8·5237	...	20 1 3·63	3	98 29 59·91	3
−7·5183	8–7	20 2 45·76	2	97 20 33·83	2
−9·5382	6–7	20 5 8·85	3	99 10 12·58	3

Observers: W.—Mr. W. Wickham; R.—Mr. W. H. Robinson; F. B.—Mr. F. A. Bellamy.

Radcliffe Observatory, Oxford:
1890 *January* 21.

Mean Right Ascensions and North Polar Distances for January 1, 1889, of Comparison Stars for the Planets Victoria and Sappho. Observed with the Cambridge Transit Circle.

(*Communicated by Professor J. C. Adams.*)

Mean Right Ascensions and Mean North Polar Distances for January 1, 1889, of Comparison Stars with the Planet Victoria. Observed with the Cambridge Transit Circle.

No. of Star.	D.M.	Month and Date. 1889.	Mag.	Mean R.A. Jan. 1, 1889.	Mean N.P.D. Jan. 1, 1889.
	°			h m s	° ′ ″
1	−6–5151	June 25	7·7	19 21 25·277	95 57 22·38
		27		25·331	22·88
		July 5		25·277	21·47
2	−6–5158	June 26	8·3	19 23 2·638	96 24 1·49
		July 8		2·858	2·49
		11		2·537	2·46
3	−5–4985	June 25	8·5	19 24 6·228	95 9 7·85
		July 5	8·5	6·376	8·27
		Aug. 3	8·5	6·299	7·78
4	−5–4989	July 23	8·4	19 25 17·954	95 54 13·15
		Aug. 5	8·4	17·960	14·00
		6	8·4	17·933	14·01
		31	8·4	17·998	13·79
5	−5–4992	June 26	8·3	19 25 40·583	95 21 3·37
		July 11	8·2	40·391	4·08
		30	8·2	40·462	4·10
		Aug. 7	8·2	40·267	3·35
		Sept. 6	8·2	40·361	4·51
6	−5–5006	June 25	7·5	19 27 50·552	94 58 51·07
		July 8	7·6	50·627	51·26
		18	7·6	50·527	49·45
		Aug. 3	7·6	50·574	50·92
		Sept. 6	7·6	50·533	50·83
7	−4 4843	June 27		19 28 37·814	94 41 25·84
		July 11	8·5	37·677	25·00
		Sept. 7		37·797	24·39
8	−4–4846	July 5	7·7	19 29 20·712	94 33 7·02
		23	7·8	20·722	6·23
		Aug. 28	7·8	20·664	6·84

No. of Star.	D.M.	Month and Date. 1889.		Mag.	Mean R.A. Jan. 1, 1889.	Mean N.P.D. Jan. 1, 1889.
	°				h m s	° ′ ″
9	−5-5021	June	25	7·8	19 30 41·190	95 1 3·77
		July	8	7·8	41·248	2·77
			18	7·7	41·265	4·62
10	−4-4855	June	26	7·5	19 30 53·644	94 32 44·64
		Aug.	15		53·349	45·15
			31		53·463	44·79
11	−3-4649	July	5	8	19 31 22·045	93 43 20·29
			23	8	22·127	19·69
12	−4-4861	June	27	5	19 31 54·011	94 53 42·04
		July	11	5	53·970	41·03
		Aug.	6	5	54·107	41·14
		Sept.	6	5	53·996	42·62
13	−5-5036	June	25	6·8	19 34 26·921	95 42 8·71
		July	5		26·973	7·61
		Aug.	17		26·969	8·91
14	4-4877	June	26	7·5	19 34 53·740	94 17 22·40
		Aug.	3	7·5	53·569	22·83
			5	7·5	53·503	22·71
			15	7·5	53·445	22·55
		Sept.	6	7·5	53·528	23·08
15	−4-4883	June	27	9·3	19 35 56·163	94 32 51·76
		July	8		56·113	50·92
			11		56·046	50·98
		Aug.	6	7·7	56·058	50·73
			28	7·7	56·074	50·70
			29	7·7	56·032	50·90
			31	7·7	56·007	51·00
16	−4-4903	June	25	8·3	19 39 23·743	94 47 23·60
		July	5		23·780	24·13
			11		23·825	24·01
		Aug.	3		23·699	23·76
17	−4-4916	June	26	7·8	19 40 59·612	93 56 0·76
		July	30	7·8	59·554	1·53
		Aug.	15	7·8	59·475	1·70
			28	7·8	59·432	1·80
		Sept.	6	7·8	59·492	2·92

No. of Star.	D.M.	Month and Date. 1889.		Mag.	Mean R.A. Jan. 1, 1889.	Mean N.P.D. Jan. 1, 1889.
	°				h m s	° ′ ″
18	−5–5060	June	27	9·3	19 41 53·546	95 30 24·49
		Aug.	5	7·8	53·319	24·69
19	−4–4926	June	26	7·8	19 43 4·588	94 46 18·68
		July	11		4·559	19·69
			30		4·551	18·97
		Aug.	3		4·540	19·68
			6		4·569	18·87
			15		4·415	20·32
			29		4·499	18·79
			31		4·546	20·48
20	−4–4936	July	5	8	19 43 43·946	94 48 25·00
		Aug.	17		44·059	26·86
21	−5–5075	Aug.	5	6·5	19 44 56·186	94 58 28·19
			28		56·039	28·34
22	−4–4960	July	5	8	19 47 27·198	94 51 33·92
			18		27·377	33·95
			30		27·460	33·15
		Aug.	3		27·211	34·03
23	−5–5099	July	23	8	19 48 22·408	95 20 0·75
		Aug.	5		22·371	1·20
			6		22·425	1·87
			15		22·415	1·49
24	−5–5120	June	25	8·2	19 51 25·987	94 58 55·31
		Aug.	3		25·885	56·05
			28		25·823	55·41
			29		25·837	55·38
25	−5–5124	June	26	8·5	19 52 3·750	95 28 59·33
		July	23		3·456	59·85
		Aug.	15		3·583	60·55
			31		3·640	61·10
26	−6–5320	June	27		19 52 18·204	96 38 57·15
		Aug.	5	8·2	18·164	57·06
			17	8·2	18·318	58·21
		Sept.	6	8·2	18·124	57·44
27	−4–4984	July	11	8·2	19 52 38·194	94 39 18·21
		Aug.	6	8·2	38·020	18·68

No. of Star.	D.M.	Month and Date. 1889.		Mag.	Mean R.A. Jan. 1, 1889.	Mean N.P.D. Jan. 1, 1889.
	°				h m s	° ′ ″
28	−4–4992	June	25	7·8	19 54 57·323	94 36 54·01
		July	23		57·369	53·05
		Aug.	28		57·371	53·92
29	−6–5339	June	26	8·2	19 55 40·014	96 40 49·46
		July	11		39·856	49 82
		Aug.	5		39·707	51·09
0	−5–5138	July	5	6·3	19 56 17·713	95 17 50·33
		Aug.	3		17·687	50·13
			6		17·622	50·41
31	−8–5205	July	23	8·1	19 57 4·862	98 0 14·07
		Aug.	15		4·834	15·26
			31		4·719	14·96
32	−5–5144	July	11	8·2	19 57 21·802	94 56 29·58
		Aug.	5		21·727	29·65
		Sept.	6		21·719	30·23
33	−6–5360	July	5	8·3	19 59 23·962	96 53 58·89
		Aug.	3	8·5	23·854	59·50
			28	8·5	23·769	57·26
			29	8·5	23·781	57·97
34	−4–5016	July	18	7·2	20 0 44·997	94 44 5·41
		Aug.	5	7·2	44·839	5·83
35	−7–5169	July	11	8·2	20 0 46·700	97 19 56·54
			23		46·675	56·31
		Aug.	6		46·817	57·06
			15		46·699	56·48
			31		46·768	55·62
36	−8–5237	July	5	7·3	20 1 3·770	98 29 59·97
		Sept.	6		3·718	60·28
37	−9–5382	June	26	6·5	20 5 9·095	99 10 11·66
			27	7	8·939	12·15
		July	5	6·3	9·009	13·06
			18	6·5	8·945	13·62
		Aug.	6	6·5	8·967	13·48
			15	6·5	8·988	12·92
			28	6·5	8·975	13·21

Observations of Stars as Culminators.

D.M.	Month and Date. 1889.	Mag.	Mean R.A. Jan. 1, 1889.	Mean N.P.D. Jan. 1, 1889.
			h m s	° ′ ″
−8°4887	June 26	5·7	19 6 39·587	98 7 27·66
	27		39·491	26·84
	July 1		39·491	27·03
	5		39·349	28·36
	11		39·454	27·79
	18		39·401	27·69
	23		39·381	27·17
	30		39·468	28·06
	31		39·507	26·58
	Aug. 3		39·518	27·19
	5		39·381	26·97
	6		39·435	27·64
	7		39·423	27·58
	15		39·535	27·46
	17		39·541	28·11
	28		39·512	27·52
	29		39·384	28·87
	31		39·446	28·25
	Sept. 6		39·406	29·27
	7		39·424	28·23
−5−4936	June 27	5	19 14 37·282	95 37 22·26
	July 1		37·349	21·55
	5		37·319	21·47
	8		37·339	23·32
	11		37·329	21·54
	17		37·320	22·47
	18		37·376	22·46
	23		37·268	21·18
	30		37·424	22·43
	Aug. 3		37·370	22·37
	5		37·326	21·37
	6		37·301	22·44
	7		37·317	22·03
	15		37·439	21·84
	17		37·302	23·16

D.M.	Month and Date. 1889.		Mag.	Mean R.A. Jan. 1, 1889.	Mean N.P.D. Jan. 1, 1889.
				h m s	° ′ ″
−5°–4936	Aug.	28		19 14 37·338	95 37 21·43
		29		37·326	22·81
		31		37·327	22·49
	Sept.	6		37·328	22·90
		7		37·361	21·72
−6–5451	June	27	6·3	20 14 31·559	96 42 28·39
	July	5		31·592	28·90
		11		31·489	28·95
		18		31·650	30·05
		23		31·414	29·83
	Aug.	28		31·379	29·65
		29		31·451	29·36
		31		31·467	29·48
	Sept.	6		31·522	29·65
−3–4888	July	5	6·3	20 19 55·077	93 9 36·79
		8		55·185	36·63
		11		55·091	36·18
		23		55·063	36·62
	Aug.	28		55·058	36·29
		29		55·114	35·77
		31		55·059	36·29
	Sept.	6		55·055	36·67

Mean Right Ascensions and Mean North Polar Distances for January 1, 1889, *of Comparison Stars with the Planet Sappho. Observed with the Cambridge Transit Circle.*

No. of Star.	D.M.	Month and Date. 1889.		Mag.	Mean R.A. Jan. 1, 1889.	Mean N.P.D. Jan. 1, 1889.
					h m s	° ′ ″
	+ 8°–101	Sept.	10	8·5	0 37 16·297	81 35 28·90
	+ 7–104		10	8	0 39 55·566	82 45 45·00
1	+ 8–110		16	7·7	0 42 25·240	81 23 2·80
			20		25·270	2·87
		Oct.	3		25·230	1·44
			7		25·196	3·30
2	+ 9–090	Sept.	17	9	0 42 31·166	80 20 50·19
			25	9	1·110	49·92

No. of Star.	D.M.	Month and Date. 1889.		Mag.	Mean R.A. Jan. 1, 1889.	Mean N.P.D. Jan. 1, 1889.
	°				h m s	° ′ ″
3	+11–102	Sept.	18	8·6	0 44 24·341	78 46 23·79
		Oct.	3		24·409	24·68
			9		24·376	24·08
4	+ 9–097	Sept.	10	8·5	0 44 46·651	80 11 35·82
			20		46·784	35·36
			25		46·779	36·34
		Oct.	7		46·645	35·36
			12		46·623	35·79
			21		46·701	35·19
5	+11–106	Sept.	16	7	0 45 46·211	77 49 6·96
		Oct.	8		46·078	6·98
			10		46·172	7·30
6	+ 9–099	Sept.	17	8·3	0 46 20·497	80 0 8·65
		Oct.	9		20·399	6·10
7	+12–104	Sept.	20	7·3	0 46 40·018	76 57 14·75
			25		40·103	15·79
		Oct.	3		40·130	15·69
8	+ 9–101	Sept.	10	8·3	0 47 0·585	80 47 55·73
			18		0·631	54·61
		Oct.	12		0·576	56·44
9	+10–105	Oct.	7	8·4	0 48 2·888	79 28 48·63
			8		2·865	48·00
			9		2·840	46·62
			10		2·974	47·54
			14		2·998	47·59
10	+12–108	Sept.	10	8·2	0 49 11·918	77 45 15·41
			16		12·045	14·05
			20		11·932	15·63
		Oct.	3		12·118	14·66
11	+13–129	Sept.	17	6·5	0 50 19·780	76 38 58·88
			25		19·760	57·78
		Oct.	7		19·673	57·61
12	+11–118	Sept.	18	8·8	0 50 40·430	77 53 15·07
		Oct.	9		40·523	14·62

No. of Star.	D.M.	Month and Date. 1889.	Mag.	Mean R.A. Jan. 1, 1889.	Mean N.P.D. Jan. 1, 1889.
	°		cc	h m s	° ′ ″
13	+13–130	Oct. 8	8·7	0 50 52·305	75 49 29·51
		10		52·342	30·08
14	+ 9–110	Oct. 12	8·7	0 50 59·096	80 35 4·24
		21		59·228	6·36
		31		59·396	4·39
15	+11–120	Sept. 10	8·2	0 51 32·776	78 10 14·49
		20		32·901	13·82
		Oct. 3		32·997	13·06
16	+12–119	Sept. 16	6	0 52 5·148	76 54 14·06
		Oct. 7		4·967	16·66
		24		5·044	16·33
		25		5·095	15·64
17	+13–143	Sept. 10	8·5	0 53 53·646	75 59 20·58
		18		53·883	21·14
		Oct. 3		53·684	21·94
18	+10–115	Sept. 16	8·2	0 55 25·630	79 24 59·98
		25		25·648	61·11
19	+11–135	Sept. 20	8	0 55 32·916	78 41 9·15
		Oct. 14		32·826	9·80
		21		32·831	9·40
		25		32·810	9·87
20	+13–150	Sept. 17	8·5	0 56 43·529	79 20 42·89
		Oct. 3	8·5	43·560	40·92
		24		43·565	43·77
		31		43·539	40·39
21	+15–154	Sept. 18	8·5	0 57 9·577	74 27 33·08
		Oct. 10		9·849	33·94
		12		9·605	32·29
22	+12–126	Sept. 20	7·8	0 57 16·380	77 32 49·48
		25		16·454	49·90
23	+13–155	Sept. 16	8·7	0 58 0·654	76 39 32·31
		Oct. 9		0·682	32·50
24	+14–163	Sept. 10	5·5	0 59 13·705	75 39 4·18
		17		13·763	4·76
		25		13·753	4·14

No. of Star.	D.M.	Month and Date. 1889.		Mag.	Mean R.A. Jan. 1, 1889.	Mean N.P.D. Jan. 1, 1889.
					h m s	° ′ ″
24	+14–163	Oct.	8	5·5	0 59 13·681	75 39 4·04
			12		13·933	3·77
			25		13·770	4·92
25	+14–168	Sept.	18	9	0 59 57·018	75 36 42·56
			20		57·076	44·10
		Oct.	9		57·127	44·09
			10		57·131	44·48
			24		57·087	45·12
26	+15–159	Sept.	16	8·5	1 0 29·723	74 16 49·53
		Oct.	31		29·670	48·91
27	+15–164	Sept.	11	8	1 1 59·509	74 43 45·28
			17		59·562	45·72
			20		59·503	44·83
			25		59·545	45·23
		Oct.	7		59·398	45·25
			14		59·475	44·32
28	+16–116	Sept.	18	8	1 2 2·013	73 10 47·71
		Oct.	8		2·215	49·11
			25		2·232	51·11
29	+16–119	Sept.	16	8·6	1 2 34·968	72 56 18·96
		Oct.	9		34·960	19·34
			10		34·924	20·20
			24		35·025	20·31
30	+14–175	Sept.	17	6·4	1 4 18·272	74 55 1·40
			18		18·158	55 0·78
		Oct.	3		18·287	54 59·84
			25		18·269	55 2·11
31	+17–166	Sept.	10	8·8	1 5 3·748	72 11 53·66
			16		3·999	53·32
		Oct.	9		3·904	54·55
32	+16–123	Oct.	7	8·5	1 5 10·297	73 48 48·68
			10		10·443	47·43
			14		10·220	47·71

No. of Star.	D.M.	Month and Date. 1889.		Mag.	Mean R.A. Jan. 1, 1889.	Mean N.P.D. Jan. 1, 1889.
					h m s	° ′ ″
33	+13–175	Oct.	8	8·2	1 5 24·071	75 53 55·36
			24		24·111	55·49
			31		24·164	52·74
34	+15–175	Sept.	10	8·3	1 6 55·791	73 49 31·16
		Oct.	9	8·5	55·862	30·78
			25	8·5	55·780	32·39
35	+15–177	Sept.	25	6·5	1 8 13·818	74 27 14·87
		Oct.	3		13·836	15·10
			7		13·776	15·87
			10		13·743	14·28
			14		13·707	14·25
			24		13·916	15·61
			31		13·875	13·76
36	+16–129	Oct.	3	8·3	1 10 15·814	72 57 6·72
			7		15·796	7·07
			8		15·756	6·29
			9		15·876	7·62
			24		15·945	7·69
			25		15·695	8·32
37	+15–185	Sept.	18	8·8	1 11 34·372	74 13 52·20
			20		34·567	51·17
			25		34·386	52·63
		Oct.	10		34·566	52·30
			31		34·496	52·09
38	+17–183	Sept.	17	8	1 12 26·053	72 0 29·15
		Oct.	3		26·221	29·27
			7		26·086	28·61
			8		26·089	28·38
			9		26·024	29·05
			14		26·001	27·45
			24		26·167	28·69
			25		25·976	29·30

Observations of Stars as Culminators.

D.M.	Month and Date. 1889.	Mag.	Mean R.A. Jan. 1, 1889.	Mean N.P.D. Jan. 1, 1889.
			h m s	° ′ ″
+10°065	Sept. 16	7·3	0 31 32·082	79 10 27·26
	17		31·985	28·80
	18		31·858	27·49
	20		32·091	28·96
	25		31·967	28·50
	Oct. 3		31·906	26·68
	7		31·964	28·41
	8		31·989	28·41
	9		32·038	27·51
	10		32·168	29·28
	12		32·091	28·33
	14		32·247	26·17
	21		32·023	28·32
	4		31·978	30·50
	25		31·966	28·37
	31		32·083	27·02
+15-106	Sept. 16	7·3	0 37 4·373	73 56 35·49
	17		4·261	38·95
	18		4·134	36·40
	20		4·323	36·64
	25		4·281	37·13
	Oct. 3		4·141	36·50
	7		4·239	37·25
	8		4·277	36·75
	9		4·334	36·31
	10		4·284	37·21
	12		4·231	36·54
	14		4·363	34·96
	21		4·278	37·40
	24		4·301	37·88
	25		4·254	36·63
	31		4·432	36·50
+10-171	Sept. 16	7	1 17 2·176	79 12 45·99
	17		2·179	47·63
	18		2·101	46·22
	20		2·255	46·99
	25		2·201	47·26

D.M.	Month and Date. 1889.		Mag.	Mean R.A. Jan. 1, 1889. h m s	Mean N.P.D. Jan. 1, 1889. ° ′ ″
+10°171	Oct.	3	7	1 17 2·300	79 12 47·22
		7		2·121	47·14
		8		2·166	46·56
		9		2·215	47·84
		10		2·217	46·47
		14		2·175	46·55
		24		2·291	48·32
		25		2·083	47·85
		31		2·222	46·80
+16–154	Sept.	16	7·2	1 22 26·012	73 29 42·55
		17		25·922	44·25
		18		25·907	43·26
		20		26·057	43·54
		25		26·085	43·84
	Oct.	3		25·934	44·44
		7		25·965	44·17
		8		25·925	43·86
		9		25·958	44·52
		10		25·989	43·96
		14		26·000	43·74
		24		26·139	44·87
		25		25·873	44·83
		31		26·151	43·56

Observations of the Satellites of Saturn: Conjunctions with the centre of the planet; of Occultations of Stars by the Moon; and of Phenomena of Jupiter's Satellites. Observed at Mr. E. Crossley's Observatory, Bermerside, Halifax, with the 9⅛-inch Cooke Refractor. Power 240. By J. Gledhill.

1886, January 11.—Very faint. *Enceladus* s. Not up at 8h 50m. Up at 8h 55m (?) Past at 9h 5m (?). Certainly past at 9h 10m. G.M.T.

January 18.—*Tethys* s. Not up at 8h 50m and 8h 55m. Past at 9h 10m.

January 26.—*Rhea.* Up at 5h 50m (?), 5h 55m (?), 6h (?). Past at 6h 5m. *Enceladus* s. Very difficult owing to haze. 10h 30m not in line. 10h 45m past.

February 2.—*Enceladus* s. Not in line at $6^h\ 45^m$. Clouds passing. Not up at $6^h\ 50^m$. Past at $7^h\ 5^m$.

February 3.—*Tethys* n. Not in line at 10^h. Past at $10^h\ 9^m$. Good definition.

February 4.—Good sky. *Enceladus* not seen. *Rhea* s. On line about $6^h\ 37^m$. *Dione* s. Up at $7^h\ 49^m$. *Tethys* s. Up at $8^h\ 42^m$.

December 2 (with the 3-foot reflector).—*Dione* s. 13^h not in line, nor at $13^h\ 2^m$; probably in line between $13^h\ 3^m$ and $13^h\ 7^m$. Past at $13^h\ 10^m$. *Mimas.* Looked long and carefully for *Mimas*; saw it steadily at $13^h\ 3^m$. *Tethys* n. Not up at $13^h\ 45^m$ and $13^h\ 50^m$; up between $13^h\ 53^m$, $13^h\ 57^m$. Past at 14^h.

December 4 (3-foot reflector).—*Mimas* not seen. *Tethys* n. Up at $11^h\ 3^m$ and past at $11^h\ 10^m$. (Mr. Crossley at telescope.)

December 20.—*Dione* n. Not up at $7^h\ 40^m$, nor at $7^h\ 42^m$. Doubtful from $7^h\ 45^m$ to $7^h\ 47^m$. Past at $7^h\ 50^m$ (?) Past at $7^h\ 51^m$.

1887, January 12.—*Dione* s. Not in line at $13^h\ 40^m$. Doubtful from $13^h\ 45^m$ to $13^h\ 50^m$. Past at $13^h\ 52^m$. Bad sky.

January 26.—*Tethys* n. Not in line at $7^h\ 5^m$. Up from $7^h\ 10^m$ to $7^h\ 15^m$. Past at $7^h\ 17^m$. *Dione* s. Not in line before $7^h\ 50^m$. Up between $7^h\ 55^m$ and 8^h. Past at $8^h\ 2^m$ (?) Past at $8^h\ 4^m$.

January 30.—*Dione* n. Not up at $8^h\ 20^m$. Up between $8^h\ 27^m$ and $8^h\ 33^m$. Past at $8^h\ 35^m$.

February 5.—*Rhea* s. Not in line before $9^h\ 23^m$. Probably up between $9^h\ 25^m$ and $9^h\ 30^m$. Past at $9^h\ 33^m$.

February 10.—*Dione* n. Up between $6^h\ 57^m$ and $7^h\ 5^m$. Past at $7^h\ 7^m$ (?). Certainly past at $7^h\ 10^m$. *Tethys* n. Not up at $9^h\ 27^m$. Probably up between $9^h\ 30^m$ and $9^h\ 35^m$.

February 11.—*Tethys* s. Not in line at 8^h. In line between $8^h\ 5^m$ and $8^h\ 10^m$. Past at $8^h\ 17^m$. The satellite unusually bright. *Enceladus* also was very well seen.

February 12.—*Tethys* n. Not up at $6^h\ 45^m$. Up between $6^h\ 50^m$ and $6^h\ 55^m$. Past at $7^h\ 3^m$.

February 14.—*Dione* s. Not on line at $9^h\ 30^m$. Probably so between $9^h\ 32^m$ and $9^h\ 40^m$. Past at $9^h\ 45^m$. *Rhea* s. Up between $10^h\ 10^m$ and $10^h\ 15^m$. Past at $10^h\ 20^m$.

February 18.—*Dione* n. Not on line at $11^h\ 50^m$. On between $11^h\ 52^m$ and $12^h\ 5^m$. Past at $12^h\ 12^m$ (?).

February 26.—*Tethys* s. Not up at $10^h\ 25^m$. Up between $10^h\ 32^m$ and $10^h\ 40^m$. Past at $10^h\ 42^m$ (?).

February 27.—*Tethys* n. Not on line at $9^h\ 10^m$. On between $9^h\ 15^m$ and $9^h\ 20^m$.

March 29.—*Rhea* n. Not up at $7^h\ 53^m$. On line between $7^h\ 55^m$ and $8^h\ 5^m$. Past at $8^h\ 10^m$.

March 31.—*Tethys* n. Not up at $11^h\ 15^m$. Up between $11^h\ 20^m$ and $11^h\ 25^m$. Past at $11^h\ 30^m$.

April 1.—*Tethys* s. Not on line at $10^h\ 5^m$. On between $10^h\ 7^m$ and $10^h\ 12^m$. Past at $10^h\ 15^m$.

April 2.—*Tethys* n. On line between 8^h 50^m and 8^h 55^m. Past at 9^h.

April 16.—*Rhea* n. Not up at 9^h 50^m. Up between 9^h 55^m and 10^h 5^m. Past at 10^h 10^m.

April 17.—*Tethys* n. On line between 11^h 20^m and 11^h 25^m. *Saturn* very low; satellite not well seen.

April 18.—*Dione* s. On line between 8^h 27^m and 8^h 37^m. Not well seen.

Tethys s. Judged on line between 9^h 57^m and 10^h 6^m. Bad sky.

April 19.—*Tethys* n. In conjunction between 8^h 40^m and 8^h 50^m. Planet low.

1890, March 29.—*Rhea* s. Not up at 8^h 35^m. Past at 8^h 43^m.

March 30.—*Enceladus* not seen.

April 2.—*Dione* n. Not up at 8^h 55^m. Past at 9^h 3^m.

Tethys in contact with the ball about 9^h (?). Uncertain.

April 3.—*Tethys* disappeared at the ball about 8^h 50^m.

April 4.—*Tethys*. Saw it well at 7^h 30^m and 7^h 40^m moving up to the ball. Could not see it at 8^h.

April 7.—*Rhea* s. Not up at 9^h 15^m. Past at 9^h 20^m. Could not see *Enceladus* for some time. In conjunction, east, between 12^h 45^m and 12^h 50^m.

April 8.—Watched for the conjunction of *Dione* and *Japetus*. Clouds prevented observation, but saw the satellites $10'' \pm$ apart about 9^h.

May 13.—*Dione* n. In conjunction about 10^h 15^m

Occultations of stars by the Moon observed with the $9\frac{1}{8}$-inch Cooke refractor. Power 240:—

1887, February 6.—3 *Cancri*. Disappearance 9^h 16^m 32^s, G.M.T.

April 2.—B.A.C. 2,731. Disappearance 9^h 15^m 12^s, G.M.T.

October 24.—θ *Capricorni*. Reappearance 5^h 51^m 31^s, G.M.T.

October 28.—B.A.C. 81. Disappearance 11^h 24^m 7^s, G.M.T.

1888, October 13. 20 *Capricorni*. Disappearance 7^h 7^m 15^s, G.M.T.

1889, January 18.—θ *Libræ*. Disappearance 10^h 50^m 28^s, G.M.T.

February 9.—*i Tauri*. Disappearance 6^h 48^m 41^s, G.M.T. Reappearance 7^h 56^m 39^s, G.M.T.

February 12.—63 *Geminorum*. Disappearance 7^h 47^m 49^s, G.M.T.

1890, April 30.—ν *Virginis*. Disappearance 11^h 53^m 27^s, G.M.T.

August 28.—37 *Capricorni*. Disappearance 11^h 19^m 14^s, G.M.T.

Phenomena of Jupiter's Satellites observed with the 9½-inch Cooke Refractor.

1885.	Satellite.	Phenomena.		G.M.T. h m s	Remarks.
Apr. 5	I.	Tr. I.	First contact	9 33	Much cloud.
	I.	Sh. I.	Just within	10 34	Much cloud.
17	II.	Sh. I.	Bisection	8 21	Good sky.
			Inner contact	8 23	
	II.	Tr. E.	Inner contact	8 57	
			Bisection	8 59½	
			Outer contact	9 0	
	II.	Sh. E.	Inner contact	11 14	Not well seen.
18	III.	Sh. E.	Inner contact	8 35	
			Just off	8 37	
	IV.	Tr. E.	Inner contact	11 30	Satellite like a dark spot from 7 P.M. till egress.
25	III.	Sh. I.	Just within	9 4	Shadow looked small and dark. At 9.30 it was dark and larger.
26	II.	Ec. R.	First seen	8 59 23	Full brightness, $9^h\ 4^m$.
27	IV.	Ec. R.	First seen	8 35 39	
May 2	III.	Tr.	Ingress not seen		The satellite was dark during transit, but not black.
6	I.	Oc. D.	First contact	8 31	
13	IV.	Oc. D.	First contact	9 27	Fair definition.
			Bisection	9 29	
			Just gone	10 1	
	I.	Oc. D.	First contact	10 24	
			Bisection	10 26	
			Disappeared	10 28½	
	III.	Ec. R.	First seen	10 37 7	Full brightness, $10^h\ 41^m \pm$.
14	I.	Tr. E.	Inner contact	10 5	
			Half off	10 7	
			Outer contact	10 9	
20	III.	Oc. R.	First seen	9 30	Definition not good.
			Just off	9 32½	
	III.	Ec. D.	Fading	11 10	
			Half gone	11 12	
			Last seen	11 15	Or $11^h\ 14^m\ 46^s$.
26	II.	Sh. I.	Bisection	10 43½	Clouds pass. Planet low. Mr. Crossley at telescope.
			Just within	10 44½	
	II.	Tr. E.	Just off	10 6	Planet low.

	Satellite.	Phenomena.	G.M.T. h m s	Remarks.
1885.				
May 30	IV.	Oc. R. First seen	8 55	Very bad sky.
		Just off	8 57	
	I.	Sh. E. Inner contact	9 37	
June 2	II.	Tr. I. First contact	9 47	Cloudy.
1886.				
Apr. 2	II.	Oc. D. First contact	9 19	Clouds pass.
4	III.	Tr. E. Outer contact	9 21	
9	I.	Oc. D. Outer contact	10 4	Good sky.
		Just gone	10 6	Transit of red spot, $10^h\ 15^m$.
	II.	Oc. D. Outer contact	11 37	
		Bisection	11 39	
		Just gone	11 41	
11	II.	Tr. E. Inner contact	8 45	Satellite invisible, mostly, during transit.
		Bisection	8 47	
		Outer contact	8 49	
	II.	Sh. E. Inner contact	9 46	
	III.	Tr. I. First contact	9 49	At $10^h\ 30^m$ the satellite was quite dark on the disc.
		Bisection	9 53	
		Inner contact	9 56	
May 18	I.	Ec. R. First seen	11 13 18	
1889.				
Aug. 22	III.	Oc. R. First seen	7 55½	Planet very low.
	I.	Sh. I. Just within	8 15½	
28	II.	Ec. R. First seen	9 18 31	Planet very low.
		Half out	9 20	
		Full	9 22	
29	III.	Oc. D. Outer contact	8 43	
		Half gone	8 46	
		Just gone	8 48½	
	I.	Tr. I. First contact	8 55	
		Bisection	8 56½	
		Inner contact	8 59	
Sept. 6	I.	Oc. D. First contact	8 9	Planet very low; bad definition.
		Disappeared	8 13	
7	I.	Tr. E. Inner contact	7 34½	Very bad definition.
		Just off	7 38	
1890.				
Sept. 7	II.	Sh. E. Last seen	8 58	
27	I.	Ec. R. First seen	7 38 59	Bad sky.

Ephemeris for Physical Observations of Jupiter, 1891. By A. Marth.

Greenwich Noon 1891.		Angle of Position of ♃'s Axis. P	L−O.	Diff.	B	Corr. of log. Δ.	Light-time.	A−O.	β	Longitude of ♃'s Central Meridian. (877°·90) I.	(870°·27) II.	Corr. for Phase.	Apparent Diameter. Equat.	Phase.	Polar.
		°	°		°		m	°	°	°	°	°	″	″	″
April	17	335·765	203·513	391	+1·005	−165	46·736	194·9068	+0·7930	216·99	32·64	+0·32	34·81	0·20	32·59
	19	·714	203·904	386	1·026	168	46·540	195·0857	·8022	172·52	332·91	·34	34·95	·21	32·73
	21	·665	204·290	380	1·046	171	46·339	195·2646	·8115	128·06	273·19	·36	35·10	·22	32·87
	23	·618	204·670	374	1·067	174	46·133	195·4435	·8207	83·61	213·47	·37	35·26	·23	33·02
	25	·572	205·044	368	1·087	177	45·924	195·6225	·8300	39·16	153·76	·39	35·42	·24	33·17
	27	335·528	205·412	361	+1·108	−179	45·710	195·8015	+0·8392	354·72	94·06	+0·40	35·59	·25	33·32
	29	·486	205·773	354	1·128	182	45·493	195·9805	·8484	310·29	34·37	·42	35·76	·26	33·48
May	1	·445	206·127	348	1·148	184	45·271	196·1596	·8576	265·87	334·69	·43	35·93	·27	33·64
	3	·406	206·475	340	1·168	186	45·046	196·3387	·8669	221·46	275 02	·45	36·11	·28	33·81
	5	·369	206·815	332	1·188	188	44·818	196·5178	·8761	177·06	215·36	·46	36·29	·29	33·98
	7	335·333	207·147	325	+1·207	−190	44·586	196·6970	+0·8853	132·67	155·71	+0·48	36·48	·30	34·16
	9	·299	207·472	318	1·227	191	44·351	196·8763	·8945	88·29	96·06	·49	36·68	·31	34·34
	11	·266	207·790	309	1·246	192	44·113	197·0556	·9036	43·92	36·43	·50	36·88	·32	34·53
	13	·235	208·099	301	1·265	194	43·872	197·2349	·9128	359·56	336·81	·51	37·08	·33	34·72
	15	·206	208·400	292	1·284	195	43·629	197·4142	·9220	315·20	277·19	·53	37·28	·34	34·91
	17	335·178	208·692	283	+1·303	−195	43·383	197·5935	+0·9311	270·86	217·59	+0·54	37·49	·35	35·11
	19	·151	208·975	275	1·322	196	43·135	197·7729	·9403	226·53	158·00	·55	37·71	·36	35·31

Greenwich Noon 1891.		Angle of Position of ♃'s Axis. P	L−O.	Diff.	B	Corr. of log. Δ.	Light-time.	A−O.	β	Longitude of ♃'s Central Meridian. (877°·90) I.	(870°·27) II.	Corr. for Phase.	Apparent Diameter. Equat.	Phase.	Polar.
		°	°		°		m	°	°	°	°	°	″	″	″
May	21	335·125	209·250	266	+1·340	−196	42·885	197·9523	+0·9494	182·20	98·42	+0·56	37·93	0·37	35·52
	23	·101	209·516	256	1·358	197	42·633	198·1318	·9586	137·89	38·84	·57	38·15	·38	35·73
	25	·078	209·772	246	1·376	197	42·380	198·3113	·9677	93·59	339·28	·57	38·38	·38	35·94
	27	335·056	210·018	237	+1·394	−197	42·125	198·4908	+0·9768	49·30	279·72	+0·58	38·61	·39	36·16
	29	·036	210·255	227	1·412	196	41·869	198·6704	0·9860	5·02	220·18	·58	38·85	·40	36·38
	31	335·017	210·482	217	1·429	196	41·612	198·8500	0·9951	320·75	160·65	·59	39·09	·40	36 60
June	2	334·999	210·699	206	1·446	195	41 354	199·0296	1·0042	276·49	101·13	·59	39·33	·41	36·83
	4	·983	210·905	196	1·463	194	41·096	199·2093	1·0132	232·24	41·62	·59	39·58	·41	37 06
	6	334·967	211·101	185	+1·479	−193	40 837	199·3890	+1·0223	188·00	342·12	+0·59	39·83	·41	37·30
	8	·953	211·286	173	1·495	192	40·578	199·5687	1·0314	143·78	282·63	·59	40·09	·42	37·54
	10	·939	211·459	162	1·511	191	40·319	199·7485	1·0405	99·57	223·16	·59	40·34	·42	37·78
	12	·927	211·621	151	1·526	189	40·061	199·9283	1·0496	55·36	163·69	59	40·60	·42	38·02
	14	·916	211·772	139	1·541	188	39·803	200·1081	1·0586	11·16	104·23	·59	40·87	·42	38·27
	16	334·906	211·911	127	+1·556	−186	39·546	200·2880	+1·0677	326·98	44·79	+0·59	41·13	·42	38·52
	18	·896	212·038	115	1·571	184	39·280	200·4679	1·0767	282·81	345·36	·58	41·40	·42	38·77
	20	·888	·153	103	1·585	182	39·036	200·6478	1·0857	238·65	285·94	·58	41·67	·42	39·02
	22	·880	·256	91	1·599	179	38·784	200·8278	1·0947	194·50	226·53	·57	41·94	·42	39·27
	24	·873	·347	79	1·612	177	38·533	201·0078	1·1037	150·36	167·13	·56	42·21	·41	39·53
	26	334·867	212·426	66	+1·625	−174	38·284	201·1878	+1·1127	106·23	107·74	+0·55	42·49	·41	39·78

Greenwich Noon		Angle of Position of ♃'s Axis. P	L−O.	Diff.	B	Corr. of log. Δ.	Light-time.	A−O.	β	Longitude of ♃'s Central Meridian. (877°·90) I.	(870°·27) II.	Corr. for Phase.	Apparent Diameter. Equat.	Phase.	Polar.
1891.		°	°		°		m	°	°	°	°	°	″	″	″
June	28	334·863	212·492	53	+1·637	−171	38·038	201·3679	+1·1217	62·12	48·36	+0·54	42·76	0·40	40·04
	30	·859	·545	40	1·649	168	37·794	201·5480	1·1307	18·02	348·99	·53	43·04	·40	40·30
July	2	·856	·585	27	1·661	165	37·554	201·7281	1·1397	333·92	289·64	·52	43·32	·39	40·56
	4	·853	·612	15	1·672	162	37·316	201·9083	1·1486	289·84	230·30	·50	43·59	·38	40·82
	6	334·852	212·627	1	+1·683	−158	37·082	202·0885	+1·1576	245·77	170·96	+0·48	43·87	·37	41·08
	8	·852	·628	12	1·693	155	36·852	202·2687	1·1666	201·71	111·64	·47	44·14	·36	41·33
	10	·852	·616	25	1·703	151	36·626	202·4490	1·1755	157·66	52·33	·45	44·41	·35	41·59
	12	·853	·591	38	1·712	147	36·404	202·6293	1·1844	113·62	353·03	·43	44·68	·34	41·84
	14	·855	·553	51	1·720	143	36·187	202·8096	1·1933	69·59	293·74	·41	44·95	·32	42·09
	16	334·858	212·502	63	+1·728	−139	35·975	202·9900	+1·2022	25·57	234·46	+0·39	45·22	·31	42·34
	18	·862	·439	76	1·736	135	35·768	203·1704	1·2111	341·55	175·18	·37	45·48	·30	41·58
	20	·866	·363	89	1·743	130	35·567	203·3508	1·2200	297·55	115 92	·35	45·74	·28	42·82
	22	·871	·274	101	1·749	126	35·372	203·5312	1·2288	253·56	56·67	·33	45·99	·27	43·06
	24	·878	·173	113	1·755	121	35·182	203·7117	1·2377	209·58	357·43	·31	46·24	·25	43·29
	26	334·886	212·060	126	+1·760	−116	34·999	203·8922	+1·2465	165·60	298·19	+0·29	46·48	·24	43·52
	28	·894	211·934	137	1·765	111	34·822	204·0727	1·2554	121·64	238·96	·27	46·71	·22	43·74
	30	·903	211·797	149	1·769	106	34·652	204·2533	1·2642	77·68	179·74	·25	46·94	·20	43·96
Aug.	1	·913	211·648	160	1·772	101	34·489	204·4339	1·2730	33·73	120·53	·23	47·16	·19	44·16
	3	·925	211·488	171	1·775	96	34·334	204·6145	1·2818	349·78	61·32	·21	47·38	·17	44·36

Greenwich Noon		Angle of Position of ♃'s Axis. P	L−O.	Diff.	B	Corr. of log. Δ.	Light-time.	A−O.	β	Longitude of ♃'s Central Meridian. (877°·90) I.	(870°·27) II.	Corr. for Phase.	Apparent Diameter. Equat.	Phase.	Polar.
1891.		°	°		°		m	°	°	°	°		″	″	″
Aug.	5	334·937	211·317	182	+1·777	− 91	34·186	204·7951	+1·2906	305·84	2·12	+0·19	47·58	0·15	44·55
	7	·950	211·135	191	1·778	86	34·046	204·9758	1·2994	261·91	302·93	·17	47·78	·14	44·74
	9	·964	210·944	201	1·779	80	33·914	205·1565	1·3081	217·98	243·74	·15	47·96	·12	44·91
	11	·979	210·743	209	1·779	75	33·791	205·3373	1·3169	174·06	184·56	·13	48·14	·11	45·08
	13	334·995	210·534	218	1·778	69	33·676	205·5181	1·3257	130·14	125·38	·11	48·30	·09	45·23
	15	335·013	210·316	226	+1·777	−63	33·570	205·6989	+1·3344	86·22	66·20	+0·09	48·46	·08	45·37
	17	·031	210·090	232	1·775	58	33·473	205·8797	1·3431	42·30	7·02	·08	48·60	·07	45·50
	19	·050	209·858	239	1·772	52	33·385	206·0606	1·3518	358·39	307·85	·06	48·72	·05	45·62
	21	·070	209·619	245	1·769	46	33·306	206·2415	1·3605	314·48	248·67	·05	48·84	·04	45·73
	23	·091	209·374	250	1·765	40	33·237	206·4224	1·3692	270·56	189·50	·04	48·94	·03	45·83
	25	335·113	209·124	255	+1·761	−34	33·177	206·6033	+1·3779	226·65	130·33	+0·03	49·03	·03	45·91
	27	·136	208·869	258	1·756	28	33·126	206·7843	1·3865	182·73	71·15	·02	49·11	·02	45 98
	29	·160	208·611	261	1·751	22	33·085	206·9653	1·3952	138·82	11·97	·01	49·17	·01	46·04
	31	·184	208·350	264	1·745	16	33·055	207·1463	1·4038	94·90	312·79	·01	49·21	·01	46·08
Sept.	2	·209	208·086	265	1·738	10	33·034	207·3274	1·4124	50·98	253·61	·00	49·24	·00	46·11
	4	335·235	207·821	265	+1·731	− 4	33·023	207·5085	+1·4210	7·05	194·42		49·26		46·12
	6	·261	207·556	265	1·723	+ 2	33·021	207·6896	1·4296	323·11	135·23		49·26		46·12
	8	·288	207·291	264	1·715	8	33·031	207·8708	1·4382	279·17	76·03	·00	49·25		46·11
	10	·315	207·027	262	1·706	14	33·050	208·0520	1·4468	235·22	16·82	−0·01	49·22	·00	46·09

Greenwich Noon		Angle of Position of ♃'s Axis. P	L−O.	Diff.	B	Corr. of log. Δ.	Light-time.	A−O.	β	Longitude of ♃'s Central Meridian. (877°·90) I	(870°·27) II.	Corr. for Phase.	Apparent Diameter. Equat.	Phase.	Polar.
1891.		°	°		°		m	s	°	°	°	°	″	″	″
Sept.	12	335·343	206·765	259	+1·697	+20	33 080	208·2332	+1·4553	191·27	317·60	−0·01	49·17	0·01	46·05
	14	335·371	206·506	256	+1·688	+26	33·119	208·4144	+1·4639	147·30	258·38	−0·02	49·11	·01	45·99
	16	·399	206·250	252	1·679	32	33·168	208·5957	1·4724	103·33	199·15	·02	49·04	·02	45·92
	18	·427	205·998	247	1·669	38	33·226	208 7770	1·4809	59·35	139·90	·03	48·96	·03	45·84
	20	·454	205·751	241	1·658	44	33 295	208·9583	1·4894	15·35	80·65	·05	48·86	·04	45·75
	22	·482	205·510	234	1·648	50	33·373	209·1396	1·4979	331·34	21·38	·06	48·74	·05	45·64
	24	335·509	205·276	228	+1·637	+56	33·460	209·3210	+1·5064	287·32	322·10	−0·07	48·62	·06	45·52
	26	·536	205·048	220	1·627	62	33·556	209·5024	1 5148	243·29	262·81	·09	48·48	·07	45·39
	28	·563	204·828	211	1·616	68	33·662	209·6838	1·5233	199·25	203·51	·10	48·32	·09	45 25
	30	·588	204·617	203	1·605	73	33 777	209 8653	1·5317	155·19	144·19	·12	48·16	·10	45·10
Oct.	2	·613	204·414	193	1·594	79	33·901	210 0467	1·5401	111·12	84·86	·14	47·98	·12	44·93
	4	335·637	204·221	183	+1·583	+85	34·033	210·2282	+1·5485	67·03	25·51	−0·16	47·80	·13	44·75
	6	·660	204·038	173	2·572	90	34·174	210·4097	1·5569	22·93	326·15	·18	47·60	·15	44·57
	8	·682	203·865	161	1·561	96	34·323	210·5913	1·5653	338·81	266·77	·20	47·39	·16	44·38
	10	·703	203·704	150	1·550	101	34·480	210·7729	1·5737	294·68	207·38	·22	47·18	·18	44·17
	12	·723	203·554	138	1·540	106	34·644	210·9545	1·5820	250·53	147·97	·24	46·95	·19	43 96
	14	335·741	203·416	125	+1·529	+112	34·816	211·1361	+1·5903	206·36	88·54	−0·26	46·72	·21	43·75
	16	·758	203·291	113	1·519	117	34·995	211·3178	1·5986	162·17	29·10	·28	46·48	·23	43·52
	18	·773	203·178	101	1·509	122	35·181	211·4995	1·6069	117·97	329·64	·30	46·24	·24	43·29

Greenwich Noon		Angle of Position of ℣'s Axis. P	L−O.	Diff.	B	Corr. of log. Δ.	Light-time.	A−O.	β	Longitude of ℣'s Central Meridian. (877°·90) I.	(870°·27) II.	Corr. for Phase.	Apparent Diameter. Equat.	Phase.	Polar.
1891.		°	°		°		m	°	°	°	°	°	″	″	″
Oct.	20	335·787	203·077	88	+1·499	+·127	35·373	211·6812	+1·6152	73·75	270·16	−0·32	45·99	0·26	43·06
	22	·799	202·989	75	1·490	131	35·571	211·8629	1·6235	29·52	210·67	·34	45·73	·27	42·82
	24	335·809	202·914	61	+1·481	+·136	35·776	212·0447	+1·6317	345·27	151·16	−0·36	45·47	·29	42·57
	26	·818	202·853	48	1·472	140	35·987	212·2265	1·6400	301·01	91·64	·38	45·20	·30	42·33
	28	·825	202·805	34	1·463	145	36·202	212·4083	1·6482	256·72	32·10	·40	44·93	·31	42·07
	30	·830	202·771	21	1·455	149	36·423	212·5901	1·6564	212·42	332·54	·42	44·66	·33	41·82
Nov.	1	·833	202·750	7	1·447	153	36·649	212·7719	1·6646	168·11	272·96	·44	44·39	·34	41·56
	3	335·835	202·743	7	+1·440	+·157	36·879	212·9538	+1·6728	123·77	213·37	−0·45	44·11	·35	41·30
	5	·834	202·750	21	1·433	161	37·114	213·1357	1·6809	79·42	153 76	·47	43 83	·36	41·04
	7	·832	202·771	34	1·427	164	37 353	213·3176	1·6891	35·06	94·13	·48	43·55	·37	40·78
	9	·828	202·805	48	1·421	168	37·595	213·4996	1·6972	350·68	34·49	·50	43·27	·38	40·51
	11	·822	202·853	62	1·416	171	37·840	213·6815	1·7053	306·28	334·84	·51	42·99	·38	40·25
	13	335·814	202·915	75	+1·411	+·174	38·088	213·8635	+1·7134	261·87	275·17	−0·52	42·71	·39	39·99
	15	·805	202·990	88	1·406	177	38 339	214·0455	1·7215	217·44	215·48	·53	42·43	·39	39·73
	17	·794	203·078	101	1·402	180	38·592	214·2275	1·7296	173 00	155·78	·54	42·15	·40	39·47
	19	·781	203·179	114	1·399	183	38·847	214·4096	1·7376	128·54	96·06	·55	41·87	·40	39·21
	21	·766	203·293	127	1·396	185	39·104	214·5917	1·7457	84·07	36·33	·55	41·60	·40	38·85
	23	335·750	203·420	140	+1·393	+·187	39·363	214·7738	+1·7537	39·58	336·59	−0·56	41·32	·40	38·69
	25	·732	203·560	152	1·391	189	39·623	214·9559	1·7617	355·08	276·83	·56	41·05	·40	38·44

Greenwich Noon	Angle of Position of ♃'s Axis. P	L−O.	Diff.	B	Corr. of log. Δ.	Light-time.	Δ−O.	β	Longitude of ♃'s Central Meridian. (877°·90) L	(870°·27) II.	Corr. for Phase.	Apparent Diameter. Equat.	Phase.	Polar.
1891.	°	°		°		m	°	°	°	°	°	″	″	″
Nov. 27	335·713	203·712	164	+1·390	+191	39·884	215·1380	+1·7697	310·57	217·06	−0·57	040·79	0·40	38·19
29	·693	203·876	177	1·389	193	40·145	215·3202	1·7776	266·05	157 28	·57	40·52	·40	37·94
Dec. 1	·671	204·053	189	1·389	194	40·407	215·5024	1·7856	221·51	97·49	·57	40·26	·40	37·69
3	335·648	204·242	200	+1·389	+195	40·669	215·6846	+1·7935	176·96	37 68	−0·57	40·00	·40	37·45
5	·623	204·442	212	1·390	196	40·931	215·8668	1·8014	132·40	337·86	·57	39·74	·39	37·21
7	·598	204·654	223	1·391	197	41·192	216·0491	1·8093	87·83	278·03	.56	39·49	·39	36·97
9	·572	204·877	234	1·392	198	41·452	216·2314	1·8172	43·25	218·19	·56	39·24	·38	36·74
11	·544	205·111	244	1·394	198	41·712	216·4137	1·8251	358·66	158·34	·55	39·00	·38	36·51
13	335·515	205·355	255	+1·397	+198	41·970	216·5960	+1·8329	314·06	98·48	−0·55	38·76	·37	36·29
15	·486	205·610	265	1·400	198	42·227	216·7783	1·8407	269·45	38·61	·54	38·52	·36	36·07
17	·456	205·875	275	1·404	198	42·482	216·9606	1·8485	224·83	338·73	·54	38·29	·36	35·85
19	·426	206·150	285	1·408	198	42·735	217·1430	1·8563	180·20	278 84	·53	38·06	·35	35·64
21	·395	206·435	294	1·413	197	42·986	217·3254	1·8641	135·56	218·95	·52	37·84	·34	35·43
23	335·363	206·729	303	+1·418	+196	43·235	217·5079	+1·8719	90·91	159·04	−0·51	37·62	0·33	35·23
25	·331	207·032	312	1·424	195	43·482	217·6903	1·8796	46·26	99·13	·49	37·41	·32	35·03
27	·299	207·344	321	1·430	194	43·725	217·8728	1·8873	1·60	39·21	·48	37·20	·31	34·83
29	·267	207·665	330	1·436	192	43·966	218·0553	1·8950	316·93	339·28	·47	37·00	·30	34·64
31	·234	207·995	338	1·443	191	44·203	218·2378	1·9027	272·26	279·35	·46	36·80	·29	34·46

Greenwich Noon		Angle of Position of ♃'s Axis. P	L−O.	Diff.	B	Corr. of log. Δ.	Light-time.	Δ−O.	β	Longitude of ♃'s Central Meridian. (877°·90) I.	(870°·27) II.	Corr. for Phase.	Apparent Diameter. Equat.	Phase.	Polar.
1892.		°	°		°		m	°	°	°	°	°	″	″	″
Jan.	2	335·201	208·333	346	+1·451	+189	44·437	218·4203	+1·9103	227·58	219·41	−0·44	36·61	0·28	34·28
	4	·169	208·679	353	1·459	187	44·667	218·6028	1·9180	182·89	159·47	·43	36·42	·27	34·10
	6	·137	209·032	361	1·467	185	44·894	218·7854	1·9256	138·20	99·52	·41	36·23	·26	33·93
	8	·105	209·393	368	1·475	182	45·116	218·9679	1·9332	93·50	39·56	·40	36·05	·25	33·76
	10	·073	209·761	375	1·484	180	45·335	219·1505	1·9408	48·80	339·60	·38	35·88	·24	33·60
	12	335·041	210·136	382	+1·493	+177	45·549	219·3331	+1·9483	4·10	279·64	−0·37	35·71	·23	33·44
	14	335·010	210·518	388	1·503	175	45·759	219·5158	1·9559	319·39	219·67	·35	35·55	·22	33·29
	16	334·979	210·906	394	1·513	171	45·964	219·6984	1·9634	274·68	159·70	·34	35·39	·21	33·14
	18	·949	211·300	401	1·524	167	46·164	219·8811	1·9709	229·96	99·72	·32	35·24	·20	32·99
	20	·920	211·701	406	1·535	164	46·360	220·0638	1·9784	185·24	39·74	·30	35·09	·19	32·85
	22	334·891	212·107	411	+1·546	+160	46·550	220·2465	+1·9859	140·51	339·76	−0·29	34·94	·18	32·72
	24	·863	212·518	417	1·557	156	46·736	220·4292	1·9933	95·79	279·78	·27	34·80	·17	32·59
	26	·836	212·935	423	1·569	152	46·916	220·6119	2·0008	51·06	219·79	·26	34·67	·16	32·47
	28	·810	213·358	427	1·581	148	47·091	220·7947	2·0082	6·33	159·80	·24	34·54	·15	32·35
	30	·785	213·785	432	1·594	143	47·261	220·9774	2·0156	321·60	99·81	·23	34·42	·14	32·23
Feb.	1	334·761	214·217	436	+1·606	+139	47·424	221·1602	+2·0229	276·87	39·82	−0·21	34·30	·13	32·12
	3	·738	214·653	440	1·619	134	47·582	221·3430	2·0303	232·14	339·83	·20	34·19	·12	32·01
	5	·716	215·093	444	1·632	130	47·734	221·5259	2·0376	187·41	279·84	·18	34·08	·11	31·91
	7	·695	215·537	448	1·646	125	47·880	221·7087	2·0449	142·67	219·85	·17	33·97	·10	31·81
	9	·675	215·985	452	1·660	120	48·021	221·8916	2·0522	97·94	159·85	·15	33·87	·09	31·72
	11	334·657	216·437		+1·674	+114	48·155	222·0745	+2·0595	53·21	99·86	−0·14	33·78	0·08	31·63

The present ephemeris is intended to be of service not only for physical observations of *Jupiter*, but also in the computations of the positions of the satellites, for which the necessary data and tables will be supplied in the next number of the *Monthly Notices*. For this reason some alterations have been made, and the data are furnished for every second, instead of every fifth, day, so that the second differences may be more easily taken into account.

The angle L−O+180° is the jovicentric longitude of the Earth, reckoned in the assumed plane of *Jupiter's* equator from O, the point of the vernal equinox of *Jupiter's* northern hemisphere, or the point of the descending node of the planet's equator on its orbit. B denotes the jovicentric latitude of the Earth above *Jupiter's* equator.

"Corr. of log. Δ" is the correction to be applied to the *Nautical Almanac* "log. of true distance from the Earth" in order to obtain the log. of the distance between the Earth at Greenwich noon and the place of *Jupiter* at the time, when the light-waves arriving at Greenwich noon left the planet. These corrected distances are to be interpolated directly for the times for which the apparent positions of the satellites are to be computed in order to get the distances which ought to be employed.

The column "Light-time" gives the interval of mean time, expressed in minutes, which light requires to traverse the corrected distance. The adopted constant for distance 1 is $498^{s}\cdot92$, corresponding to the constant of aberration $20''\cdot492$.

The angle Λ−O+180° is the jovicentric apparent longitude of the Sun or Λ−O the longitude of the axis of the shadow-cone, β the latitude of the Sun above *Jupiter's* equator.

The two values of the "longitude of ♃'s central meridian" given for each date are computed with the same rates of rotation as in the ephemerides for several preceding oppositions; but in "system II." the zero-meridian has been put back 10° or the longitudes have been increased 10°, so that the great spot, in case it keeps to the adopted rate, may just follow the zero-meridian. Should the motion become more settled, the time will have arrived for the proper investigation of its fluctuations since the appearance of the spot in 1879. According to Mr. A. S. Williams's interesting observations of *Jupiter's* spots, made in 1890, and published in the *Journal of the British Astronomical Association*, vol. i. pp. 116–119, "the bright equatorial zone appeared in a remarkable state of quiescence. Conspicuous markings were hardly ever seen. . . ." The two bright spots of 1888, on the observed motions of which the daily rate $877^{\circ}\cdot90$ depends (*vide M. N.* vol. xlix. pp. 88 and 94), do not seem to have been recognised under such altered conditions in 1890, but as the motions of the two markings, of which some observed transit-times are published, are approximately represented by the rate adopted in system I. of the ephemeris, I have made no alteration. It is to be hoped that during the ensuing more

favourable apparition of *Jupiter* the surface of the planet will be assiduously scrutinised, and the times of transits of all the more remarkable spots and markings across the middle of the disc carefully recorded.

The differences of successive values of the longitudes of 4's central meridian vary for I. between 1755°·28 and 1756°·08, and for II. between 1740°·02 and 1740°·82.

The addition of the "correction for phase" to the longitudes of the central meridian gives the longitudes of the meridian which bisects the illuminated disc. The following is a list of Greenwich mean times, when the zero-meridian in the assumed two systems of longitudes will pass the middle of the disc. The times between successive passages vary between $10^h\ 50^m{\cdot}40$ and $50^m{\cdot}68$ in the first system, and between $10^h\ 55^m{\cdot}58$ and $55^m{\cdot}86$ in the second.

	I. (877°·90)	II. (870°·27)		I. (877°·90)	II. (870°·27)
1891.	h m	h m	1891.	h m	h m
Apr. 17	13 44·6	18 57·0	May 10	12 56·6	13 3·1
18	19 16·4	14 48·5		22 47·1	22 58·9
19	14 57·6	20 35·8	11	8 37·7	8 54·6
20	20 29·3	16 27·3		18 28·2	18 50·3
21	16 10·5	12 18·8	12	14 9·3	14 41·8
22	11 51·6	18 6·1	13	9 50·4	10 33·3
23	17 23·4	13 57·6		19 41·0	20 29·0
24	13 4·5	19 44·9	14	15 22·1	16 20·4
25	18 36·3	15 36·4	15	11 3·2	12 11·9
26	14 17·4	11 27·9		20 53·7	22 7·6
27	9 58·6	7 19·4	16	6 44·3	8 3·3
	19 49·2	17 15·2		16 34·8	17 59·0
28	15 30·3	13 6·7	17	12 15·9	13 50·5
29	11 11·4	8 58·2		22 6·4	23 46·2
	21 2·0	18 53·9	18	7 57·0	9 41·9
30	16 43·1	14 45·4		17 47·5	19 37·6
May 1	12 24·3	10 36·9	19	13 28·6	5 33·3
	22 14·8	20 32·6		23 19·1	15 29·1
2	8 5·4	6 28·4	20	9 9·7	11 20·5
	17 56·0	16 24·1		19 0·2	21 16·2
3	13 37·1	12 15·6	21	14 41·3	17 7·6
	23 27·8	22 11·4	22	10 12·5	12 59·1
4	9 18·3	8 7·1		20 12·9	22 54·8
	19 8·8	18 2·8	23	6 3·4	8 50·5
5	14 49·9	13 54·3		15 53·9	18 46·2
6	10 31·0	9 45·8	24	11 35·0	14 37·6
	20 21·6	19 41·5		21 25·5	24 33·3
7	16 2·7	15 33·0	25	7 16·1	10 29·0
8	11 43·8	11 24·5		17 6·6	20 24·8
	21 34·4	21 20·2	26	12 47·7	6 20·5
9	7 24·9	7 15·9		22 38·2	16 16·2
	17 15·5	17 11·7	27	8 28·7	12 7·6

1891.	I. (877°·90) h m	II. (870°·27) h m
May 27	18 19·2	22 3·3
28	14 0·3	7 59·0
	23 50·8	17 54·7
29	9 41·3	13 46·1
	19 31·9	23 41·8
30	5 22·4	9 37·5
	15 12·9	19 33·2
31	10 53·9	15 24·6
	20 44·5	25 20·3
June 1	6 35·0	11 16·0
	16 25·5	21 11·7
2	12 6·5	7 7·4
	21 57·0	17 3·1
3	7 47·6	12 54·5
	17 38·1	22 50·1
4	13 19·1	8 45·8
	23 9·6	18 41·5
5	9 0·1	14 32·9
	18 50·6	24 28·6
6	14 31·7	10 24·3
	24 22·2	20 20·0
7	10 12·7	6 15·7
	20 3·2	16 11·4
8	15 44·2	12 2·7
	25 34·7	21 58·4
9	11 25·2	7 54·1
	21 15·7	17 49·8
10	7 6·2	13 41·1
	16 56·7	23 36·8
11	12 37·7	9 32·5
	22 28·2	19 28·2
12	8 18·7	15 19·5
	18 9·2	25 15·2
13	13 50·2	11 10·9
	23 40·7	21 6·6
14	9 31·2	7 2·2
	19 21·7	16 57·9
15	15 2·7	12 49·2
	24 53·2	22 44·9
16	10 43·7	8 40·6
	20 34·2	18 36·3
17	6 24·7	14 27·6
	16 15·2	24 23·3
18	11 56·1	10 18·9
	21 46·6	20 14·6

1891.	I. (877°·90) h m	II. (870°·27) h m
June 19	7 37·1	6 10·3
	17 27·6	16 5·9
20	13 8·6	11 57·2
	22 59·1	21 52·9
21	8 49·5	7 48·6
	18 40·0	17 44·2
22	14 21·0	13 35·5
	24 11·5	23 31·2
23	10 2·0	9 26·9
	19 52·5	19 22·5
24	15 33·4	15 13·8
25	1 23·9	1 9·5
	11 14·4	11 5·2
	21 4·9	21 0·8
26	6 55·3	6 56·5
	16 45·8	16 52·1
27	12 26·8	12 43·4
	22 17·2	22 39·1
28	8 7·7	8 34·7
	17 58·2	18 30·4
29	13 39·1	14 21·7
	23 29·6	24 17·3
30	9 20·0	10 13·0
	19 10·5	20 8·6
July 1	14 51·4	15 59·9
2	0 41·9	1 55·6
	10 32·4	11 51·2
	20 22·9	21 46·8
3	6 13·3	7 42·5
	16 3·8	17 38·1
4	11 45·7	13 29·4
	21 35·2	23 25·0
5	7 25·6	9 20·7
	17 16·1	19 16·3
6	12 57·0	15 7·6
	22 47·5	25 3·2
7	8 37·9	10 58·9
	18 28·4	20 54·5
8	14 9·3	6 50·1
	23 59·8	16 45·8
9	9 50·2	12 37·0
	19 40·7	22 32·7
10	5 31·1	8 28·3
	15 21·6	18 23·9
11	11 2·5	14 15·2

1891.	I. (877°·90) h m	II. (870°·27) h m
July 11	20 52·9	24 10·8
12	6 43·4	10 6·4
	16 33·8	20 2·1
13	12 14·7	5 57·7
	22 5·2	15 53·3
14	7 55·6	11 44·6
	17 46·1	21 40·2
15	13 27·0	7 35·8
	23 17·4	17 31·4
16	9 7·9	13 22·7
	18 58·3	23 18·3
17	14 39·2	9 13·9
	24 29·6	19 9·5
18	10 20·1	15 0·8
	20 10·5	24 56·4
19	6 1·0	10 52·0
	15 51·4	20 47·6
20	11 32·3	6 43·2
	21 22·7	16 38·9
21	7 13·2	12 30·1
	17 3·6	22 25·7
22	12 44·5	8 21·3
	22 34·9	18 16·9
23	8 25·3	14 8·1
	18 15·8	24 3·7
24	13 56·6	9 59·4
	23 47·1	19 55·0
25	9 37·5	5 50·6
	19 27·9	15 46·2
26	15 8·8	11 37·4
	24 59·2	21 33·0
27	10 49·6	7 28·6
	20 40·1	17 24·2
28	6 30·5	13 15·4
	16 20·9	23 11·0
29	12 1·8	9 6·6
	21 52·2	19 2·2
30	7 42·6	14 53·4
	17 33·0	24 49·0
31	13 13·9	10 44·6
	23 4·3	20 40·2
Aug. 1	8 54·7	6 35·8
	18 45·2	16 31·4
2	14 26·0	12 22·6
	24 16·4	22 18·2

1891.	I. (877°·90) h m	II. (870°·27) h m
Aug. 3	10 6·8	8 13·8
	19 57·3	18 9·4
4	5 47·7	14 0·6
	15 38·1	23 56·2
5	11 18·9	9 51·8
	21 9·4	19 47·4
6	6 59·8	5 42·9
	16 50·2	15 38·5
7	12 31·0	11 29·7
	22 21·4	21 25·3
8	8 11·8	7 20·9
	18 2·3	17 16·5
9	13 43·1	13 7·7
	23 33·5	23 3·3
10	9 23·9	8 58·9
	19 14·3	18 54·4
11	14 55·2	14 45·6
12	0 45·6	0 41·2
	10 36·0	10 36·8
	20 26·4	20 32·4
13	6 16·8	6 28·0
	16 7·2	16 23·6
14	11 48·1	12 14·7
	21 38·5	22 10·3
15	7 28·9	8 5·9
	17 19·3	18 1·5
16	13 0·1	13 52·7
	22 50·5	23 48·3
17	8 40·9	9 43·8
	18 31·3	19 39·4
18	14 2·1	15 30·6
19	0 2·5	1 26·2
	9 52·9	11 21·8
	19 43·4	21 17·3
20	5 33·8	7 12·9
	15 24·2	17 8·5
21	11 5·0	12 59·7
	20 55·4	22 55·3
22	6 45·8	8 50·8
	16 36·2	18 46·4
23	12 17·0	14 37·6
	22 7·4	24 33·2
24	7 57·8	10 28·8
	17 48·3	20 24·3
25	13 29·1	6 19·9

1891.	I. (877°·90) h m	II. (870°·27) h m
Aug. 25	23 19·5	16 15·5
26	9 9·9	12 6·7
	19 0·3	22 2·2
27	4 50·7	7 57·8
	14 41·1	17 53·4
28	10 21·9	13 44·6
	20 12·3	23 40·2
29	5 2·7	9 35·7
	15 53·1	19 31·3
30	11 33·9	5 26·9
	21 24·3	15 22·5
31	7 14·7	11 13·7
	17 5·2	21 9·2
Sept. 1	12 46·0	7 4·8
	22 36·4	17 0·4
2	8 26·8	12 51·6
	18 17·2	22 47·2
3	4 7·6	8 42·8
	13 58·0	18 38·3
4	9 38·8	4 33·9
	19 29·3	14 29·5
5	5 19·7	10 20·7
	15 10·1	20 16·3
6	10 50·9	6 11·9
	20 41·3	16 7·5
7	6 31·7	11 58·6
	16 22·1	21 54·2
8	12 3·0	7 49·8
	21 53·4	17 45·4
9	7 43·8	3 41·0
	17 34·2	13 36 6
10	13 15·1	9 27·8
	23 5·5	19 23·4
11	8 55·9	5 19·0
	18 46·3	15 14·6
12	4 36·7	11 5·8
	14 27·2	21 1·4
13	10 8·0	6 56 9
	19 58·4	16 52·5
14	5 48·8	2 48·1
	15 39·3	12 43·7
15	11 20·1	8 35·0
	21 10·6	18 30·6
16	7 1·0	4 26·2
	16 51·4	14 21·8

1891.	I. (877°·90) h m	II. (870°·27) h m
Sept. 17	2 41·9	10 13·0
	12 32·3	20 8·6
18	8 13·2	6 4·2
	18 3·6	15 59·8
19	3 54·0	1 55·4
	13 44·5	11 51·0
20	9 25·3	7 42·3
	19 15·8	17 37·9
21	5 6·2	3 33·5
	14 56·7	13 29·1
22	10 37·5	9 20·3
	20 28·0	19 16·0
23	6 18·4	5 11·6
	16 8·9	15 7·2
24	1 59·3	1 2·8
	11 49·7	10 58·4
25	7 30·6	6 49·7
	17 21·1	16 45·3
26	3 11·5	2 40·9
	13 2·0	12 36·6
27	8 42·9	8 27·8
	18 33·4	18 23·5
28	4 23·8	4 19·1
	14 14·3	14 14·7
29	9 55·2	10 6·0
	19 45·6	20 1·6
30	5 36·1	5 57·3
	15 26·6	15 52·9
Oct. 1	1 17·0	1 48·5
	11 7·5	11 44·2
2	6 48·4	7 35·5
	16 38·9	17 31·1
3	2 39·4	3 26·8
	12 19·8	13 22·4
4	8 0·8	9 13·7
	17 51·2	19 9·4
5	3 41·7	5 5·0
	13 32·2	15 0·7
6	9 13·2	0 56·3
	19 3·6	10 52·0
7	4 54·1	6 43·3
	14 44·6	16 38·9
8	0 35·1	2 34·6
	10 25·6	12 30·2
9	6 6·5	8 21·6

1891.	I. (877°·90) h m	II. (870°·27) h m
Oct. 9	15 57·0	18 17·2
10	1 47·5	4 12·9
	11 38·0	14 8·5
11	7 19·0	9 59·9
	17 9·5	19 55·6
12	3 0·0	5 51·2
	12 50·4	15 46·9
13	8 31·4	1 42·6
	18 21·9	11 38·2
14	4 12·4	7 29·6
	14 2·9	17 25·3
15	9 43·9	3 21·0
	19 34·4	13 16·6
16	5 14·9	9 8·0
	15 5·5	19 3·7
17	0 56·0	4 59·4
	10 46·5	14 55·0
18	6 37·5	0 50·7
	16 28·0	10 46·4
19	2 18·5	6 37·8
	12 9·0	16 33·5
20	7 50·1	2 29·2
	17 40·6	12 24·9
21	3 31·1	8 16·3
	13 21·6	18 12·0
22	9 2·7	4 7·7
	18 53·2	14 3·4
23	4 43·7	9 54·8
	14 34·2	19 50·5
24	0 24·8	5 46·2
	10 15·3	15 41·9
25	5 56·3	1 37·6
	15 46·9	11 33·3
26	1 37·4	7 24·7
	11 27·9	17 20·4
27	7 9·0	3 16·1
	16 59·5	13 11·8
28	2 50·1	9 3·3
	12 40·6	18 59·0
29	8 21·7	4 54·7
	18 12·2	14 50·4
30	4 2·8	0 46·1
	13 53·3	10 41·9
31	9 34·4	6 33·3
	19 24·9	16 29·0
Nov. 1	5 15·5	2 24·7

1891.	I. (877°·90) h m	II. (870°·27) h m
Nov. 1	15 6·0	12 20·5
2	0 56·6	8 11·9
	10 47·1	18 7·7
3	6 28·3	4 3·4
	16 18·8	13 59·1
4	2 9·4	9 50·6
	11 59·9	19 46·3
5	7 41·0	5 42·1
	17 31·6	15 37·8
6	3 22·2	1 33·5
	13 12·7	11 29·3
7	8 53·8	7 20·8
	18 44·4	17 16·5
8	4 35·0	3 12·2
	14 25·5	13 8·0
9	0 16·1	8 59·5
	10 7·7	18 55·2
10	5 47·8	4 51·0
	15 38·4	14 46·7
11	1 29·0	0 42·5
	11 19·5	10 38·2
12	7 0·7	6 29·7
	16 51·2	16 25·5
13	2 41·8	2 21·2
	12 32·4	12 17·0
14	8 13·6	8 8·5
	18 4·1	18 4·3
15	3 54·7	4 0·0
	13 45·3	13 55·8
	23 35·9	23 51·3
16	9 26·5	9 47·3
17	5 7·7	5 38·9
	14 58·2	15 34·6
18	0 48·8	1 30·4
	10 39·4	11 26·2
19	6 20·6	7 17·7
	16 11·2	17 13·5
20	2 1·8	3 9·2
	11 52·4	13 5·0
21	7 33·6	8 56·6
	17 24·2	18 52·3
22	3 14·8	4 48·1
	13 5·4	14 43·9
23	8 46·6	0 39·7
	18 37·2	10 35·4
24	4 27·8	6 27·0

		I. (877°·90)	II. (870°·27)
1891.		h m	h m
Nov.	24	14 18·4	16 22·8
	25	0 9·0	2 18·6
		9 59·6	12 14·3
	26	5 40·8	8 5·9
		15 31·4	18 1·7
	27	1 22·0	3 57·5
		11 12·6	13 53·3
		21 3·2	23 49·1
	28	6 53·8	9 44·9
	29	2 35·1	5 36·4
		12 25·7	15 32·2
		22 16·3	25 28·0
	30	8 6·9	11 23·8
Dec.	1	3 48·1	7 15·4
		13 38·7	17 11·2
	2	9 20·0	3 7·0
	3	5 1·2	8 54·4
	4	0 42·5	4 46·0
		10 33·1	14 41·8
	5	6 14·3	0 37·6
		16 4·9	10 33·4
	6	1 55·6	6 25·0
		11 46·2	16 20·8
	7	7 27·4	2 16·6
		17 18·1	12 12·4
	8	3 8·7	8 4·0
		12 59·3	17 59·8
	9	8 40·6	3 55·6
		18 31·2	13 51·4
	10	4 21·8	9 43·0
	11	0 3·1	5 34·7
		9 53·7	15 30·5
	12	5 35·0	1 26·3
		15 25·6	11 22·1
	13	1 16·2	7 13·7
		11 6·9	17 9·5
	14	6 48·2	3 5·4
		16 38·8	13 1·2
	15	2 29·4	8 52·8
	16	8 1·4	4 44·4
	17	3 42·6	0 36·1
		13 33·3	10 31·9
	18	9 14·6	6 23·5
	19	4 55·9	2 15·2
		14 46·5	12 11·0
		24 37·1	22 6·8

		I. (877°·90)	II. (870°·27)
1891.		h m	h m
Dec.	20	10 27·8	8 2·7
	21	6 9·1	3 54·3
		25 50·4	23 46·0
	22	11 41·0	9 41·8
	23	7 32·2	5 33·4
	24	3 3·6	1 25·1
		12 54·3	11 20·9
	25	8 35·6	7 12·6
	26	4 16·9	3 4·2
		23 58·2	22 55·9
	27	9 48·8	8 51·7
	28	5 30·1	4 43·4
	29	1 11·4	0 35·1
		11 2·1	10 30·9
	30	6 43·4	6 22·6
	31	2 24·7	2 14·2
		12 15·4	12 10·1
		22 6·0	22 5·9
1892.			
Jan.	1	7 56·7	8 1·7
	2	3 38·0	3 53·4
		23 19·3	23 45·1
	3	9 10·0	9 40·9
	4	4 51·3	5 32·6
	5	0 32·6	1 24·3
		10 23·3	11 20·1
	6	6 4·6	7 11·8
	7	1 45·9	3 3·5
		11 36·6	12 59·3
		21 27·2	22 55·2
	8	7 18·9	8 51·0
	9	2 59·2	4 42·7
		12 49·9	14 38·6
		22 40·6	24 34·4
	10	8 31·2	10 30·2
	11	4 12·5	6 21·9
		23 53·9	26 13·6
	12	9 44·5	12 9·5
	13	5 25·9	8 1·2
	14	1 7·2	3 52·8
		10 57·9	23 44·5
	15	6 39·2	9 40·4
	16	2 20·5	5 32·1
		22 1·9	25 23·8
	17	7 52·5	11 19·6
	18	3 33·9	7 11·3

	I. (877°·90)	II. (870°·27)		I. (877°·90)	II. (870°·27)
1892.	h m	h m	1892.	h m	h m
Jan. 18	23 15·2	17 7·2	Jan. 29	5 22·0	1 23·5
19	9 5·9	3 3·0	30	1 3·4	7 11·0
20	4 47·2	8 50·6	31	6 35·4	3 2·7
21	0 28·6	4 42·3	Feb. 1	2 16·7	8 50·3
22	6 0·6	0 34·0	2	7 48·8	4 42·0
23	1 41·9	6 21·5	3	3 30·1	0 33·7
24	7 15·0	2 13·2		23 11·5	20 25·4
25	2 55·3	8 0·8	4	9 2·1	6 21·3
26	8 27·3	3 52·5	5	4 43·5	2 13·0
27	4 8·7	9 40·0		14 34·1	22 4·7
28	9 40·7	5 29·8	6	0 24·8	8 0·5

Errata in Mr. Turner's Note on the Recent Determination of the Longitude of Paris, Vol. LI. No. 3.

Page 156, line 2, *for* 44 13·75 *read* 44 13·86
" " 3, *for* 9 21·16 *read* 9 21·05
" " 12, *for* 19 2·12 *read* 19 2·23
" " 13, *for* 9 21·19 *read* 9 21·08

[I am indebted to Professor Th. Albrecht for calling my attention to the note on p. 131 of *Astr. Nachr.* No. 2265, which indicates the necessity of these changes. An erroneous correction to the meridian of France was applied in forming the results published under the references given in my paper. The diagram on p. 156 should, of course, be altered accordingly.]

Page 163, footnote, second line, *for* 12 feet, or 0"·01, *read* 20 feet, or 0"·02.

[The numbers given in the text are correct, but a final correction was not extended to the footnote.]

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LI. APRIL 10, 1891. No. 6

Lieut.-General J. F. TENNANT, R.E., C.I.E., F.R.S., President, in the Chair.

John Billington Booth, J.P., Preston, Lancashire; and Hannibal Mirabita, 134 Strada Britannica, Alexandria,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Richard Edward Synge Cooper, Gentleman, Hillmorton Paddox, Rugby (proposed by J. C. Adams);
Hugh Frank Newall, Trinity College, Cambridge (proposed by H. H. Turner); and
Samuel H. Ridge, B.A., F.R.G.S., 275 Victoria Parade East, Melbourne, Victoria (proposed by P. Edward Dove).

Sixty-five presents were announced as having been received since the last meeting, including amongst others :—

Annales de l'Observatoire de Paris (Mémoires), tome xix., presented by the Observatory; Œuvres complètes de Laplace, tome viii., presented by the Academy of Sciences, Paris.

Sirius. By S. W. Burnham, M.A.

It may not be generally known, even by those who have given special attention to observing or investigating the *Sirius* system, that all the collections of the measures of the companion hitherto published are not only very incomplete with respect to the number of measures which have been made, but contain many material errors in the observations quoted and made use of. Errors of one sort and another, first made long ago, have been handed down, and, remaining unchallenged, have come to be overlooked altogether. Many years ago I undertook to collect all the measures that have been made of every known double star, and the more important notes and papers referring to them, and have since added the current measures and observations, so that the history of each double star is substantially complete to this time. I have endeavoured to make these references to *Sirius* cover the various points of interest connected with it as a double star, commencing with the investigation which resulted in the discovery of the companion by Mr. Alvan G. Clark, and especially to include all measures of the small star since the first observation in 1862. The time will soon come when a complete list of these measures will be more important than it has been heretofore, for the close determination of the real period of this interesting binary. Down to this time the result must necessarily be only approximate, since the companion has moved through less than 90° of its orbit, and the real dimensions of the apparent ellipse cannot be rigidly determined. In a few years more, and probably as soon as the companion can be seen by any telescope now in use, it will have added 180° to the arc already passed over, and then a single measure will enable the period to be computed with a very small percentage of error. This important additional measure I trust can be made with the Lick telescope within the next four or five years.

In view of the new interest which this system will then have for both the observer and the computer, I have thought it important to make as perfect a collection as possible of the published observations for the benefit of all concerned. In nearly every instance I have referred to the original publication, and there obtained the figures here given. In many cases this has been necessary to avoid the errors frequently made by taking the measures from second-hand sources. As an illustration of this, I may mention one or two examples.

In some of the collected observations, Challis is credited with having measured the companion in 1862. As a matter of fact he did not measure it, and, so far as I know, never attempted to. This measure was really made by Chacornac. Gledhill gives a different result to both Challis and Chacornac, which doubtless

led to a repetition of the same error by Gore and Howard in their computations of the orbit.

Each one of these authorities has given a set of measures by Mitchel as made in 1863. This is an obvious mistake, as it is well known that General Mitchel for some time previous to this was in the military service of the United States, and engaged in the more important work of suppressing the rebellion. He died in October 1862. These measures were really made by Marth, not in 1863, but in 1864. Marth did not observe *Sirius* in 1863 at all, although he is put down as having done so by the authors previously referred to.

Gore gives a measure in 1885 credited to the Paris Observatory; and Howard includes this with the measures used in computing a new orbit published a few weeks ago (Gould's *Astronomical Journal*, 235), and also gives a measure in 1884 from the same observatory. These two measures are as follow:—

1884·27	36°·3	8″·70	Paris Obs.
1885·11	34·1	8·09	Paris Obs.

Now these two measures are identical in date, angle, and distance with the observations of Young in 1884 and 1885, and, as I have found no authority elsewhere for these measures, I conclude that they should have been credited to Princeton instead of Paris.

To enable those who wish to consult these measures to do so conveniently, I have given, following the measures, a complete list of the works in which every measure cited can be found. The authors of the papers are given in alphabetical order, but the names of all the observers do not appear in this way, as in some instances the measures of other observers are included under one name. It should be remarked also that some of the references do not relate to micrometrical measures, but have some other special interest, and should be included in a list of valuable papers on *Sirius*.

The following are the measures I have collected:—

Measures of Sirius.

1862.

1862·19	84°·6	10″·07	Bond	3*n*
1862·20	85·0	10·09	Rutherfurd	5*n*
1862·23	84·5	10·42	Chacornac	2*n*
1862·28	83·8	(4·92)	Lassell	1*n*

1863.

1863·21	82°·5	10″·15	Otto Struve	2*n*
1863·15	88·4	7·63	Secchi	1*n*
1863·21	81·3	9·54	Rutherfurd	6*n*
1863·23	84·9	10·00	Dawes	1*n*
1863·27	82·8	...	Bond	1*n*

		1864.		
	°	"		
1864·14	79·4	10·60	Marth	3*n*
1864·18	80·1	9·63	Lassell	1–3*n*
1864·22	78·6	10·70	Bond	4–2*n*
1864·22	74·8	10·92	Otto Struve	6–3*n*
1864·23	84·9	...	Dawes	1*n*
1864·24	79·7	10·08	Winnecke	1*n*
		1865.		
	°	"		
1865·21	77·6	10·59	Otto Struve	2*n*
1865·22	75·5	9·59	Secchi	8*n*
1865·23	77·8	10·77	Förster	5–4*n*
1865·25	76·9	...	Tietjen	3*n*
1865·26	76·0	...	Bond	...
1865·26	76·9	(9·0)	Engelmann	1*n*
		1866.		
	°	"		
1866·07	77·2	10·43	Knott	2–1*n*
1866·21	...	10·74	Bruhns	1*n*
1866·21	75·2	10·93	Otto Struve	3*n*
1866·22	73·9	10·97	Tietjen	2–1*n*
1866·23	74·1	11·29	Förster	3–1*n*
1866·23	74·0	10·21	Hall	2–3*n*
1866·23	74·9	10·57	Newcomb	3*n*
1866·25	78·3	10·34	Tuttle	1*n*
1866·26	74·7	10·09	Eastman	3*n*
1866·29	71·3	10·11	Secchi	3*n*
		1867.		
	°	"		
1867·02	74·2	11·15	Winlock	7–6*n*
1867·10	73·8	10·66	Searle	6–5*n*
1867·22	72·1	10·98	Otto Struve	1*n*
1867·24	72·3	...	Förster	2*n*
1867·27	74·9	9·92	Eastman	2–1*n*
		1868.		
	°	"		
1868·02	73·2	10·25	Searle	2*n*
1868·04	72·1	...	Peirce	1*n*
1868·23	70·3	11·25	Vogel	7*n*
1868·24	69·6	11·35	Bruhns	5*n*
1868·26	71·7	10·95	Engelmann	5*n*

1869.

1869·10	74°·7	10″·26	Brünnow	7–4*n*
1869·15	73·6	11·23	Vogel	3*n*
1869·20	68·7	11·17	Dunér	1*n*
1869·20	68·6	11·07	Winlock	2*n*
1869·23	69·4	10·93	Peirce	1*n*

1870.

1870·13	68°·1	11″·16	Peirce	12–4*n*
1870·17	65·9	11·06	Winlock	7–5*n*
1870·24	65·1	12·06	Vogel	5*n*

1871.

1871·16	65°·9	10″·75	Secchi	3*n*
1871·20	70·3	11·19	Peirce	2–1*n*
1871·23	64·1	11·11	Dunér	2*n*
1871·25	60·1	12·10	Pechüle	4–3*n*

1872.

1872·18	59°·8	11″·05	Dunér	2*n*
1872·24	62·4	11·50	Newcomb	1*n*
1872·24	64·3	11·46	Hall	6*n*
1872·26	61·3	...	Skinner	3*n*

1873.

1873·20	65°·8	11″·12	Hall	1*n*
1873·22	60·8	10·57	Dunér	1–4*n*

1874.

1873·93	65°·0	11″·29	Wilson & Seabroke	1*n*
1874·16	59·0	11·46	Newcomb	7*n*
1874·19	58·7	10·99	Holden	2–1*n*
1874·23	58·0	11·10	Hall	2*n*

1875.

1874·83	57°·5	″ ...	Burton	1*n*
1875·19	57·1	10·73	Dunér	4*n*
1875·21	56·6	11·41	Newcomb	2*n*
1875·21	55·9	11·89	Holden	5–4*n*
1875·28	56·4	11·08	Hall	4*n*

		1876.		
1876·03	57°8	11″12	Watson	1*n*
1876·05	54·6	11·45	Peters	1*n*
1876·09	54·9	11·82	Holden	6*n*
1876·14	55·0	11·55	Russell	4*n*
1876·22	55·2	11·19	Hall	6*n*
		1877.		
1877·11	52°8	11″19	Cincinnati	4–3*n*
1877·16	52·8	11·35	Holden	4*n*
1877·26	53·4	10·95	Hall	5*n*
		1878.		
1877·97	52°4	10″83	Burnham	8*n*
1878·07	50·5	11·07	Holden	4*n*
1878·15	51·0	10·71	Cincinnati	9*n*
1878·19	54·4	11·24	Pritchett	5*n*
1878·22	53·2	11·4	Eastman	...
1878·24	51·7	10·76	Hall	5*n*
		1879.		
1878·70	50°0	10″61	Cincinnati	20–14*n*
1879·05	50·7	10·44	Burnham	10*n*
1879·12	47·8	11·35	Holden	5*n*
1879·15	50·3	10·78	Pritchett	5*n*
1879·20	50·1	10·55	Hall	6*n*
		1880.		
1879·75	46°5	10″29	Cincinnati	1*n*
1880·00	48·8	10·55	Russell	1*n*
1880·10	47·1	10·48	Holden	4*n*
1880·11	48·3	10·00	Burnham	11*n*
1880·17	49·6	9·87	Hough	3*n*
1880·22	51·1	...	Smith	1*n*
1880·25	47·8	10·30	Hall	8*n*
1880·28	48·6	10·38	Frisby	2*n*
		1881.		
1881·07	46°3	9″77	Burnham	8*n*
1881·12	43·3	10·83	Holden	2*n*
1881·17	46·9	10·11	Frisby	6*n*
1881·18	46·5	9·81	Young	7*n*
1881·26	45·3	9·60	Hough	5*n*
1881·26	45·3	10·00	Hall	6*n*

1882.

1881·99	43°6	9″38	Burnham	11*n*
1882·13	43·1	9·30	Hough	9*n*
1882·18	42·2	9·95	Frisby	6*n*
1882·23	42·5	9·67	Hall	7*n*
1882·54	44·0	...	Engelmann	6*n*

1883.

1883·10	40°1	9″05	Burnham	10*n*
1883·10	39·0	9·41	Young	1*n*
1883·12	39·7	9·02	Hough	11*n*
1883·14	41·3	...	Wilson	4*n*
1883·17	41·4	9·75	Frisby	7*n*
1883·21	39·1	9·26	Hall	6*n*

1884.

1884·05	36°0	9″67	Perrotin	6*n*
1884·18	36·7	8·51	Hough	11*n*
1884·19	36·4	8·39	Burnham	10*n*
1884·23	37·7	8·81	Hall	8*n*
1884·27	36·3	8·70	Young	5*n*

1885.

1885·11	34°1	8″09	Young	8*n*
1885·20	32·7	7·96	Hough	10*n*
1885·27	34·7	8·06	Hall	8*n*

1886.

1886·05	29°8	7″59	Young	4*n*
1886·14	28·7	7·21	Hough	12*n*
1886·22	30·6	7·39	Hall	6*n*

1887.

1887·14	25°4	7″08	Young	4*n*
1887·19	23·7	6·78	Hough	7*n*
1887·23	24·2	6·51	Hall	4*n*

1888.

1888·24	23°·3	5″·78	Hall	3*n*

1889.

1888·97	13°·9	5″·27	Burnham	5n

1890.

1890·27	359°·7	4″·19	Burnham	3n

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Knott.	Mems. R.A.S. xliii.—Mon. Not. xxvi. 243.
Laugier.	A.N. 1142.
Lassell.	Mon. Not. xxiv. 145.—A.N. 1360.
Leavenworth.	Publications of the McCormick Observatory, vol. i. part 4.
Mädler.	A.N. 304.
Marth.	Mon. Not. xxiv. 145.
Main.	Mon. Not. xx. 202.
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Perrotin.	Annales de l'Observatoire de Nice, vol. ii.—A.N. 2684.
Pechüle.	A.N. 1855.
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Struve, O.	Mon. Not. xxiv. 149; xxvi. 268.—Mélanges Mathématiques et Astronomiques, iii. 558 (including measures by Winnecke).
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Tempel.	A.N. 1472, 2166.
Vogel.	A.N. 1767, 1804.
Washington.	Washington Observations, 1866, 1872–79.—A.N. 1888, 2061, 2097, 2147, 2213, 2324 (measures by Hall, Holden, Newcomb, Eastman, and others).
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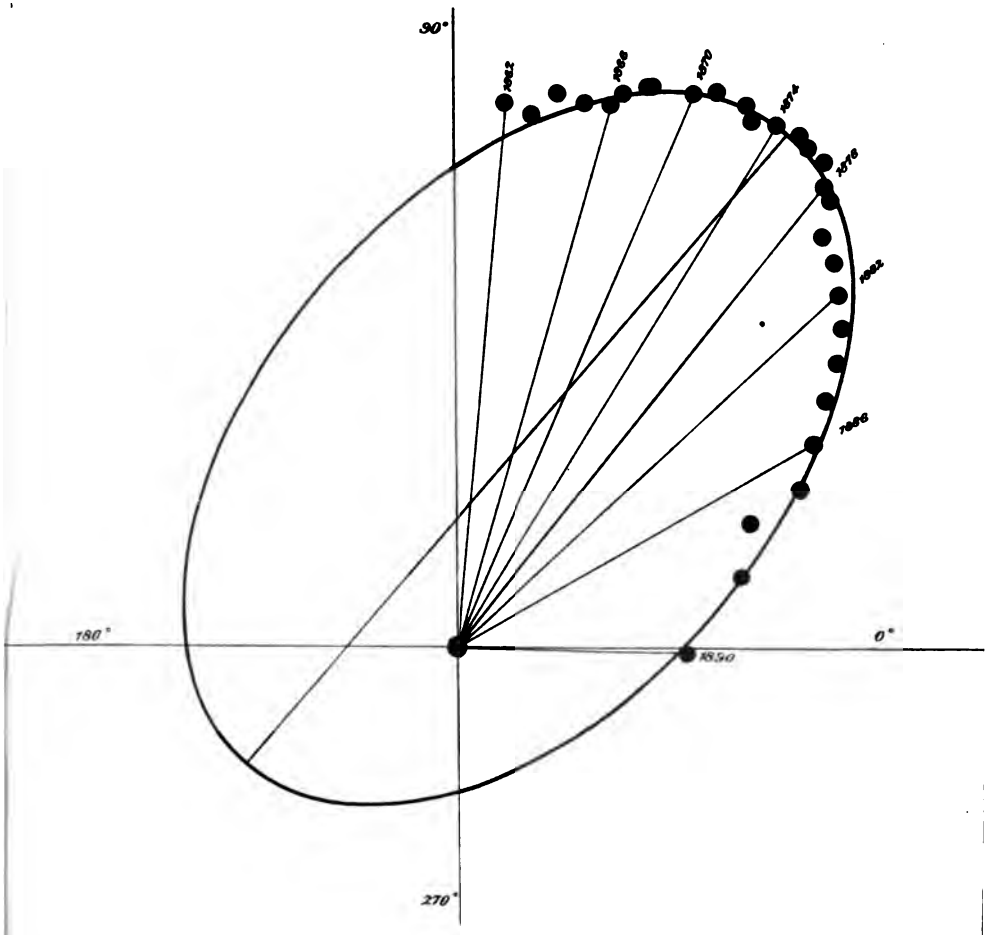
The Period of Sirius.

Some early attempts were made to see how far the motion of the observed star agreed with the theoretical companion, but the arc described was so short, and the motion of the smaller star so nearly uniform, that no reliable result could be reached from the observations. An ellipse of almost any magnitude would satisfy the observed positions as well as one which agreed with that laid down for the theoretical star. In 1881 Plummer pointed out that a period of 440 years would represent the observations about as well as one of fifty years. Since that time the limits of the possible ellipses which could be drawn through the observed positions have been greatly narrowed by the later measures, and the uncertainty of the period of rotation correspondingly reduced.

Two orbits have been recently computed: one by Gore, using measures made each year down to 1889, who finds a period of 58·47 years; and the other by Howard, who includes the very last measures of the companion made here in 1890, and obtains a period of 57·02 years. Very few of the measures are used by the last-named computer, and some of the years are not represented at all. The measures are not always correctly given, and in one instance at least the error is a large one. This occurs in a set of measures made by me in 1877. The mean result was derived from measures on eight nights. Some of these were at the end of 1877, and some in the beginning of 1878. In the paper referred to these are given as two series: one embracing the observations of 1877, and the other those of 1878, with an error of 1″ in the latter distance. Of course, these measures all belong together, and should be represented by a single mean, as given in the original publication.

The close agreement in the periods obtained by these independent investigations is worthy of note, and perhaps no better result could be got from the material available at this time. However, I have made a rough investigation in the same direction, which is given here for what it is worth. I have followed a plan which differs somewhat from that usually adopted in this: I have taken the complete series of measures given above, and deduced from the observations of each year a result which in my judgment would best represent, so far as the measures are concerned, the position of the companion. Of course this involved a consideration of the probable merits and value of each set of measures, as derived from the skill and experience of the observer, the size of the instrument used, the number of nights,



SIRIUS

S. W. Burnham, del.

and the general movement of the small star from the observations as a whole. It is not claimed that this method should be generally followed, since it would require a thorough familiarity with the relative value of measures by the different double star observers which many would have no opportunity of acquiring, but for the purpose I had in view in this instance it was certainly as good as any other.

The positions obtained in this manner are as follow:—

1862·20	85°·0	10″·08	1877·18	53°·0	11″·16
1863·22	82·9	9·90	1878·12	51·7	10·77
1864·20	79·6	10·38	1879·02	50·3	10·59
1865·22	77·0	10·32	1880·18	48·6	10·06
1866·21	74·5	10·39	1881·19	45·8	9·79
1867·17	73·4	10·68	1882·12	43·1	9·45
1868·16	71·4	10·95	1883·14	39·6	9·11
1869·17	71·0	10·93	1884·22	36·8	8·60
1870·15	67·0	11·11	1885·19	33·8	8·04
1871·21	65·1	11·29	1886·14	29·7	7·40
1872·22	62·2	11·34	1887·19	24·4	6·79
1873·21	60·8	11·12	1888·24	23·3	5·78
1874·19	58·6	11·18	1888·97	13·9	5·27
1875·22	56·5	11·28	1890·27	359·7	4·19
1876·22	55·2	11·19			

These positions were plotted on a sufficiently large scale to lay them down accurately to the decimal places. The time covered by the measures was separated into four-year intervals by the lines shown on the diagram (plate 5), and after repeated trials a satisfactory ellipse was drawn which would make these areas equal with slight changes in the position-angles. This ellipse gives a period of 53 years.

This result may not be any nearer the true time than the periods found by Gore and Howard, as it is undoubtedly true that an ellipse with a greater major axis, and consequently a longer period, would represent the arc already described by the companion about as well as any other. With reference to this matter, I have been influenced by one consideration which could not have been taken into account in the previous attempts to compute the period. I measured *Sirius* last year (1890) with the 36-inch telescope, but in consequence of my absence on the Eclipse Expedition to Cayenne, and the severe winter weather that prevailed on Mount Hamilton for some time after my return, *Sirius* was long past meridian before I could get it even in early twilight; the companion was therefore very hard to see at all, and the measures were made with extreme difficulty.

This I attributed to the unfavourable conditions, and expected to have no trouble in seeing and measuring the small star this year. I have tried to get it this year under very favourable circumstances, when the most difficult and close pairs were comparatively easy, and have utterly failed to see the least trace of it; I am satisfied that it is now beyond the reach of any telescope in the world. The distance, according to my measures in 1890, was 4″·19. It seems hardly possible that it could have been wholly invisible this year under the conditions named, if the diminution in the distance is only 0″·7, as it should be according to the orbits of Gore and Howard. I have, therefore, concluded that the small star is approaching *Sirius* more rapidly, and that the change in distance must be decidedly larger, and certainly not less than 1″, and consequently have drawn the shorter ellipse as more likely to represent the real motion. According to this, the distance at the time of my last attempts to see the companion was 3″·1, and it is not at all improbable that, at this distance from a star as bright as *Sirius*, it would be lost in the overpowering brilliancy of the large star, even with the Lick telescope. For these reasons I think a period of 53 years is not likely to be too short.

If this ellipse is correct the minimum distance will be 2″·4 in 1892–5, and about the end of 1894 the distance will be the same as at the time of my last measures. At that time, therefore, I trust the large telescope will supply observations which will definitely settle most of the uncertainties in the orbit of this interesting system.

Lick Observatory:
1891 *February* 26.

Invisible Double Stars. By S. W. Burnham.

In addition to a large number of double stars which have been seen and measured in the regular way, we have now a new class of binaries which may be designated as invisible double stars, since they have never been seen, and are only recognised from certain peculiarities in their appearance or motions. What is known of them is due to comparatively recent investigations. It can hardly be said that their existence has been proven in any instance, and the *primâ facie* case made is not always very strong. This might be expected when it is considered that the inference is deduced from observations more or less in error; and as the difficulty of eliminating any real change from errors of observation much larger in amount is very great, the result must be received with a good deal of allowance, and particularly so when the time embraced by the observations is limited.

The latest additions to this class of double stars are due to the spectroscope, which has shown a periodical doubling of

certain lines, which, it is inferred, must be caused by the alternate approach and recession of the components of a close double star in rapid motion. This method has both the advantages and the disadvantages of being entirely independent of former methods of observing. It is unaffected by the errors and imperfections of other observers; and the conclusions derived from it are without reference to what has been seen and done before; while on the other hand there has been as yet no confirmation of the correctness of these conclusions by the spectroscope or by the telescope. Of the revelations of this instrument in showing regular periodical changes in the spectrum there can be no doubt. Whatever there is of uncertainty is in the interpretation to be given to this phenomenon. At present the most probable, if not the only explanation is that this is due to the extraordinarily rapid revolution of two suns about each other. This may be the true theory, but it might be unwise or unsafe to claim at present that this recurrent phenomenon could not be due to some other cause. The wonders already accomplished by the spectroscope indicate its possibilities in the future, and the most advanced worker would hardly either limit its revelations hereafter, or say how much that is accepted now may not ultimately require some modification. It is always unsafe to rely too implicitly on any theory for the interpretation of observations which appears probable because no better can be suggested. Astronomy is perhaps at the head of the sciences in mistakes of this kind, although at the time these theories were brought forward, from the standpoint of knowledge as it then existed, the conclusions arrived at appeared to be sound and justifiable. Thus far the spectroscopic method of discovering new double stars does not seem to have been verified by applying it to stars known to be double, and, so far as appears, it has not been attempted. While there can be no hope of finding any known binaries with the remarkably short periods assigned to the late discoveries with the spectroscope, there must be many having sufficiently rapid relative motion to be entirely suitable to prove beyond all question that this is or is not the true explanation. A few trials of the close and short period binaries would probably settle at once whatever doubt there may be in this regard. Most of the known binaries are probably fainter than the stars discovered in this way, but that is not a very serious matter in photographing the spectrum, since the same result is reached by continuing the exposure sufficiently long. It is not necessary to go on photographing a pair in which this doubling of the lines is found. It is enough that it appears at all.

The other class of stars supposed to be double is due to apparent irregularities in their motions, as shown by meridian and micrometrical observations. With the single exception of *Sirius*, all the stars of this kind have remained visually single, or rather the supposed disturbing body has resisted all attempts to see it with the most powerful instruments. The results of the

most careful watching of these stars have been so uniformly negative that one is led to expect very little based upon evidence of this kind; and the double star discoverer would be justified in coming to the conclusion that the surest way of finding a single star is to look at one which, according to theoretical considerations, must certainly be double.

Too much reliance has been placed upon the infallibility of observations. It is always much more probable that the apparent irregularities of motion are due to the unavoidable errors of observation than that a star in the system sufficiently important to produce such a real effect should be at all times invisible.

The double star of this class which appears to stand upon the most substantial basis, and which has been most thoroughly investigated from what might be termed theoretical data, is *ζ Cancri*. From the irregularities in the motion of the more distant star around A B, it was inferred that it was a close pair, or attended by a fourth star; and Seeliger in an exhaustive analytical investigation has shown that the third star, C, with its invisible companion appear to rotate in about 17½ years. Perhaps no double star in the heavens has been more systematically measured than *ζ Cancri*. For more than 60 years we have more or fewer measures every year. During this interval the known close pair, A and B, have completed more than one revolution; and around these stars C has moved through an arc of 35°. This triple received special attention at Pulkowa, and the observations of O Σ cover a period of 40 years. Dembowski also measured it for many years, and most of the leading double star observers have given it more or less time. Therefore, the material to work with for any purpose is as good as would be found relating to any pair. The peculiar grouping of the positions of C was noticed a long time ago in the Pulkowa measures, and the existence of some third disturbing body suspected. Then followed finally Seeliger's investigation previously referred to.

In examining a matter of this kind the first step is to lay down all the observations accurately to scale, so that the eye can take in at a glance the entire movement of the stars as shown by the measures. This cannot be done by an inspection of tabulated results in whatever shape they may be put. The second step is to ascertain whether the peculiarities of motion are found in other and similar pairs, because, if these apparently discordant positions are rather the rule than the exception, it would go far to prove that they were due to inaccurate measures, and not to any mysterious disturbing influence.

An examination of the measures of the star C of *ζ Cancri* shows that the positions of that star are not distributed uniformly, but grouped more or less regularly along the path of its motion. This has been taken to mean that from some disturbing cause, not heretofore recognised, the motion of the star is alternately accelerated and retarded; and as this could be produced in one way

by a fourth, unseen, star, it is therefore assumed that C is attended by a dark star, the mass of which is about the same as that of C.

Being curious to know just how far such an assumption would appear to be warranted by the actual observations, I have selected measures representing as nearly as possible every year since the first observation by Struve, and have laid them down on a large scale, shown in a reduced form in the accompanying diagram (plate 6). All of the years from 1826 to 1888 inclusive are represented except 1827, 1829, 1830, 1834, 1837, 1838, 1839, and 1841. Preference has been given to the measures of Struve and O. Struve, and, when these were not to be had, to the measures of Dembowski, Dunér, Dawes, and other experienced observers. The vertical scale on the left gives the position-angles, and the scale on the top the distances. The sequence of the measures is shown by the lines joining the successive places. The time-scale on the right is made by dividing the whole interval covered by the measures into equal parts.

It is unnecessary to refer to what is shown by this diagram. The whole history of this star, so far as the measures are concerned, can be seen at a glance. The arrangement of the observed positions is certainly suggestive of some variation; and there is no doubt that the three groups of positions occur at substantially equal intervals. The question whether this is due to errors of observation is not an easy one to solve, if we consider only these observations. To show the relation between the observed and theoretical positions of C, I have given the latter, as computed by Seeliger, by the side of the actual measures, and on the same scale.

The next step was to find out, if possible, if any such peculiar motion of the companion star was shown by the measures of any other pair. To make the case parallel, it was necessary to select pairs having slow motion in position-angle of 15° to 35°, and which had been frequently measured during the same or an equal period of time. There are stars of this kind which have about the same angular velocity as ζ *Cancri*, differing not enough in distance to sensibly change the errors of measurement, and which have been measured largely by the same observers who observed the pair in question. Of course these would all be old and familiar pairs, and necessarily among the easiest objects in the heavens to measure. Among the stars selected as suitable for this purpose are *Castor*, ϵ^2 *Lyræ*, ζ *Aquarii*, γ *Leonis*, ι *Leonis*, ξ *Scorpii*, and ϵ *Hydræ*. I have plotted the measures of each of these stars in the same way (plates 7 to 9), and on the same scale, as the measures of ζ *Cancri*, and they are therefore strictly comparable. It should be noted that none of these stars have been as frequently measured as ζ *Cancri*, and, therefore, any peculiarity in the arrangement of the positions would be less prominently marked.

We find in each of these stars not only the same tendency to a grouping of the positions, but in some of them they occur at

intervals quite as regular as those of ζ *Cancri*. Take *Castor*, for instance (for which we have fifty-one measures, 1819–1878), and we find, if these groups of measures are to be taken as real, that the companion may be supposed to be revolving round a dark star once in about eight years. The circles which I have drawn round the groups are 0″·5 in diameter, and the years attached to them give the mean dates of the included observations.

In ζ *Aquarii* (1821–1871) we have similar discordances, and with a little imagination these variations might appear to recur periodically.

In ϵ^2 *Lyræ* (1819–1877) there is the same appearance, more or less regular, of accelerated and retarded motion, but only half of the years are represented by measures, and, therefore, the grouping of the measures is not so well shown.

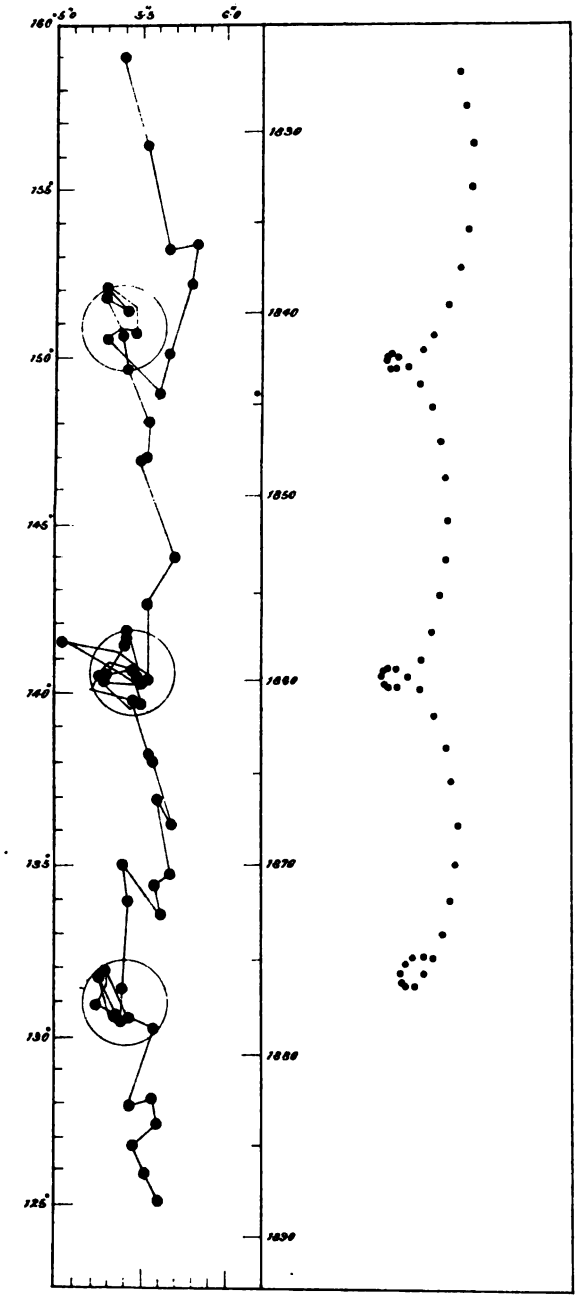
In ξ *Scorpii* there is one very strongly marked group, with few and scattering positions on each side. This is a triple star, similar in all respects to ζ *Cancri*, the third star in each case being measured from a close pair. About three-fourths of the years (1820–1877) are represented by measures.

In γ *Leonis* three distinct groups are fairly well marked at intervals of ten years, ending with 1872. The years for which there are no measures are all previous to 1845, with the single exception of 1849. The angular motion is less than that of most of the other pairs represented.

In ε *Hydræ* (1825–1889) we have three fairly well defined groups with an apparent period of thirteen years. There are twenty-one years not represented by measures, of which fifteen are previous to 1851. Eight of these missing years would come within the range of the 1844 period. It is well known that in this instance the principal star is a close pair, but it is much too close to have any influence whatever on the measures. The maximum distance probably does not exceed 0″·25, and this, with unequal components, could not possibly affect the measures with any telescope. Even with the 36-inch it would not be recognised as a double star with any power that would ordinarily be used in measuring C. There is probably no doubt that Schiaparelli's pair is moving, and perhaps rapidly. My measures indicate a motion in angle of about 16° per annum.

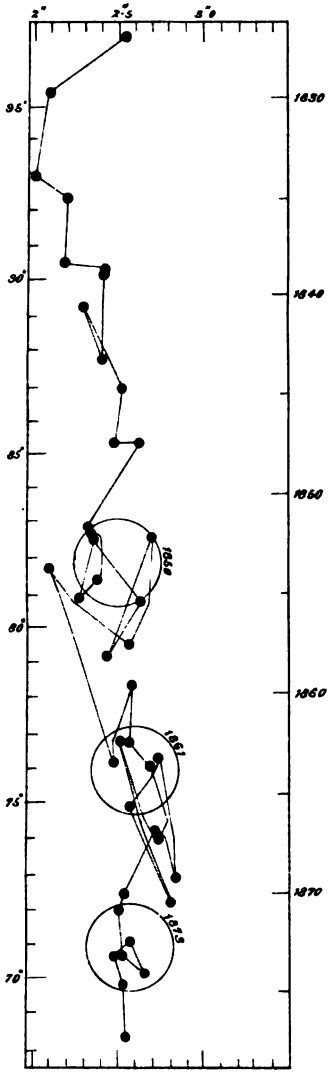
It is evident that orbits could be computed for at least some of these stars which would satisfy the observations as well as has been done in the case of ζ *Cancri*, since it is only necessary to have the groups of measured positions occur at substantially regular intervals.

It should be stated that these apparent peculiarities of motion are not exceptional in stars of this class. I have given here the diagram of every star whose record I have investigated, with the single exception of ε *Equulei*, which is omitted because the whole angular change is only 10°, and this is but a little more than the average error of many of the measures. I am satisfied from these examples, and from looking over the measures of

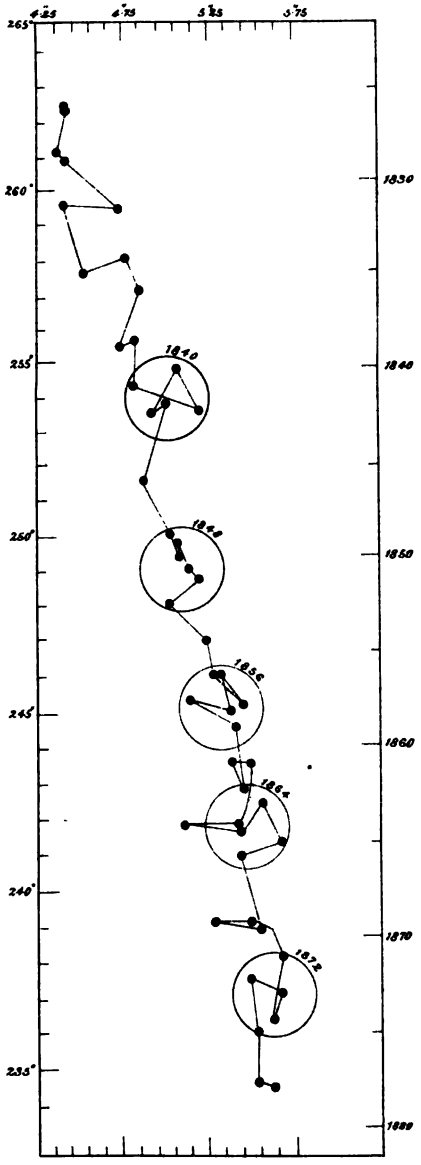


ζ CANCRI

S. W. Burnham, del. Stottiswoode & C.

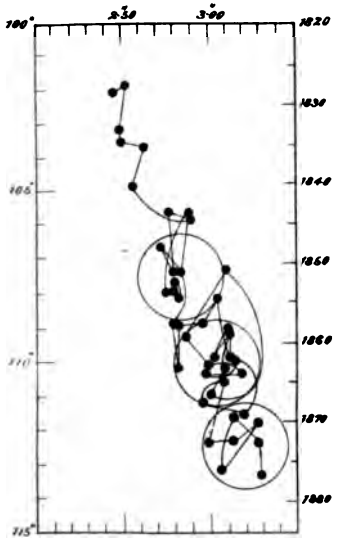


ζ LEONIS.

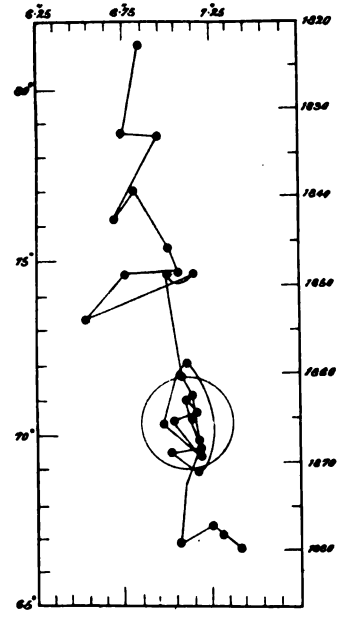


CASTOR.

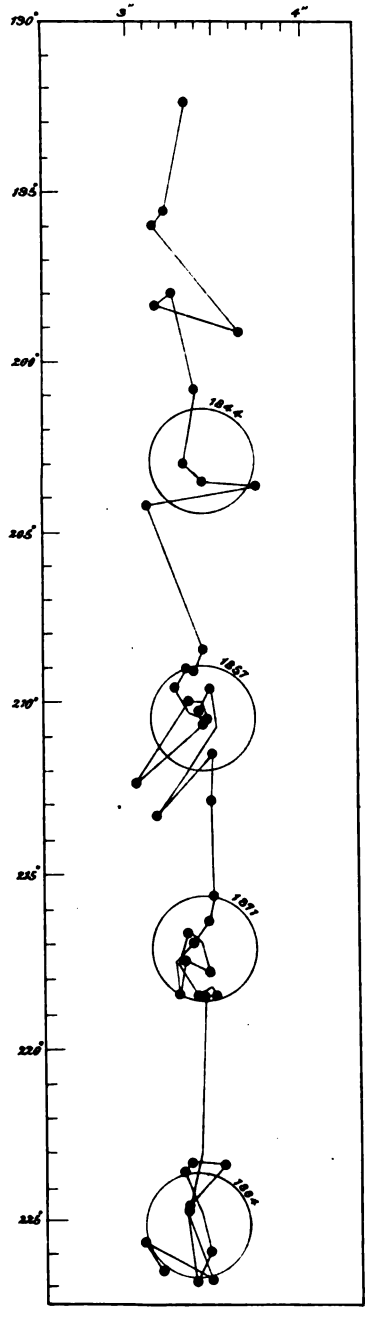
S. W. Burnham del.



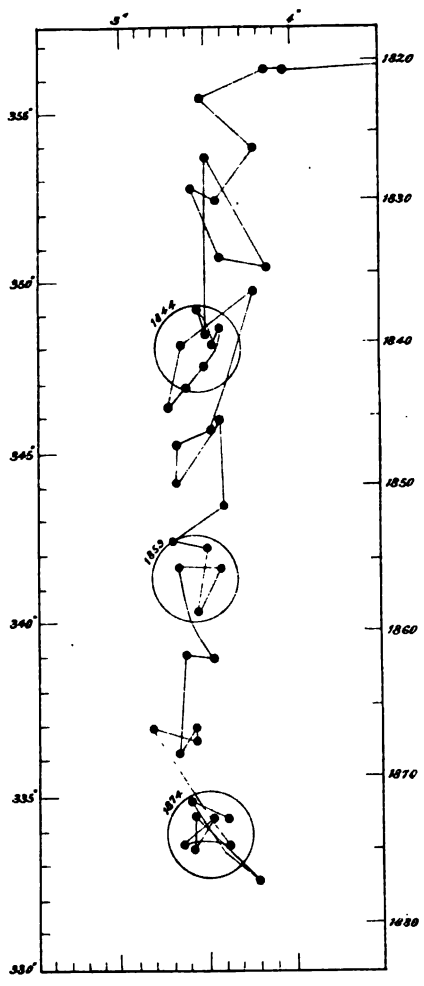
γ LEONIS



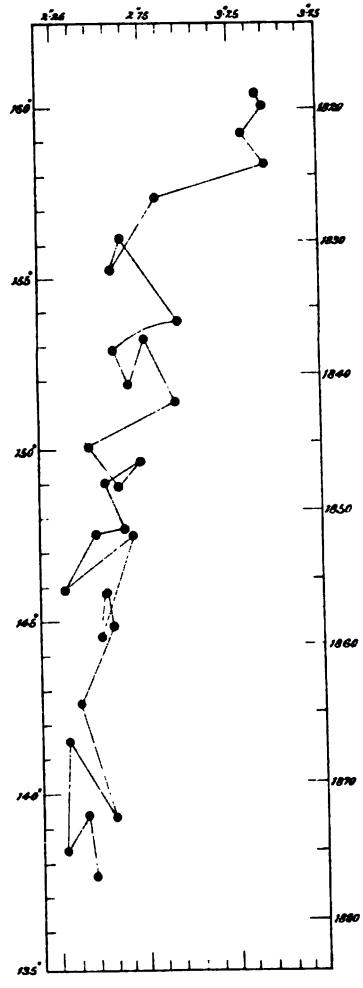
ξ SCORPII



ϵ HYDRAE



ζ AQUARII



ε LYRAE.

S. W. Burnham, del.

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other stars of this kind, that similar discordances or peculiarities will be found in all. A partial explanation at least will readily suggest itself when it is remembered that all of these stars have a general movement of only about half a degree per year; and as the average error of the measures of angle is decidedly more than that, and in many instances several times that amount, it follows that apparent retrograde movements and groups of positions must be shown where there are annual measures. There is nothing extraordinary in such a case of the positions of even half a dozen years falling in about the same place; and that there is nothing wonderful in the crowding together of the positions at nearly equal intervals is demonstrated by the frequency with which it occurs.

It is unnecessary to discuss the question how far, if at all, *ζ Cancri* differs from the other pairs referred to. With the graphical representations of the several movements before him, each one can decide this matter for himself as intelligently as if he had canvassed and investigated the whole subject. It is not so much a matter for mathematical inquiry as for the exercise of sound judgment in considering whether any or all of these discordances are due to errors of observation.

The observer who has spent a good many years of his life in the discovery of new double stars, and particularly after finding new and more difficult components in scores of the old pairs, would be the last to say that a component of *ζ Cancri*, or of any other double star in the heavens, was not itself double. One never looks at an old pair without expecting to find a new star, and it is certainly as promising a place for discovery as any other. The most that any observer can say is that any given star, if double, is beyond the power of his telescope.

Leaving out of view for the moment the various stars mentioned as illustrations of apparent changes, and assuming that the variations of the star C of *ζ Cancri* are real, there is another, and perhaps a more natural explanation of variable motion, and that is that the centre of gravity of A and B is not in the middle of the line joining the two stars. It is infinitely more probable that two stars of about the same brightness have unequal masses than that a third nearly as bright star is balanced by one of the same mass which cannot be seen at all. Of course this would not produce a similar recurrence in point of time, but would help to explain the variations shown by the measures.

There is also a special possible source of error in the measures of C, due to the fact that in many of the observations A and B are treated as one star, and the measures made from the assumed middle of the double or elongated disc. Every practical worker with the micrometer knows how much uncertainty in both angles and distances there is in measures made under such circumstances. This is not a close pair, and even when the distance is minimum it would be called a comparatively easy object with

modern telescopes; and yet these stars at this time are more than 10° apart as seen from C. This would require the observer to guess at the middle point of an arc of 10°, which is constantly changing its angle with the bisecting line. That this alone would be the cause of considerable error there can be no doubt. It is not easy to bisect a line at right angles; it is still more difficult to bisect an oblique line. It may be worth while to point out as a fact, having possibly some significance in this connection, the relation of these lines at the times of the critical positions of C. The dates given are the mean epochs of the groups of C as actually measured.

	A B and C.	A and B.	
1842	151°	360°	29°
1859	141	290	31
1877	131	100	31

It will be seen that the line joining A B and C makes practically the same angle with A and B at each of these periods, or about 30°.

Another fact may be mentioned as a curious coincidence, if nothing more. The orbital motion of A B is in the same direction as the general motion of C around that pair. In 17 years C moves forward 10°, so that A B make exactly a quarter of a revolution with reference to the place of C during one rotation of the theoretical pair, and therefore the lines connecting the three stars have the same angular rotation for each period, and recur in the same order.

If the apparent change in C is not due to any fourth dark star, but is caused by errors of observation, augmented perhaps by some of the sources of error mentioned, it then follows that with a repetition of the same kind of observations we shall have the same grouping of positions at substantially the same intervals; and, therefore, such a recurrence will be no proof of the existence of a fourth star. In view of the actual measures of this star, taken in connection with the similar variations shown in the measures of other stars where there is no question of any disturbing influence, it seems certain that special observations will have to be made of this star, using every precaution to eliminate as far as possible all sources of error in order to determine, first, whether there is any real variation in its motion; and secondly, if there is, to what is it due? One method is to measure it from A and B separately, with instruments of sufficient separating power so that the other member of the closer pair shall affect the bisection of the one being measured from as little as possible. If measurements of this kind are not made with instruments of the best definition, and under the most favourable atmospheric conditions, it is quite certain that there will be an appreciable error in the distances, and particularly in the angles; and even then it may not be possible to get rid of

the effect of one star in measuring another star so near it. Obviously the best way, and the only independent one, would be to measure C from some entirely outside point.

The nearest star at all available for this purpose is D. M. +18°, 1870, a 9·1 magnitude star, which is 286″ from C in the direction of 108°·2. As this is nearly in the line joining A B and C (123°) it would be sufficient to measure the angle only, and this could be done with great accuracy; but the distance is so great, the resulting errors of observation might still be too large to determine whether the angular motion of C is uniform. However, some of the other pairs mentioned doubtless have convenient stars to be tested with the micrometer in this manner, for it can hardly be questioned that the same explanation will apply equally to all.

Perhaps the best independent method in the case of *ζ Cancri* would be to compare C with a neighbouring star, measuring annually the difference of declination with the meridian-circle. The changes in the place of C, according to theory, should be now, and for several years to come, principally in declination, and this should be shown by differential meridian observations covering a series of years. There is a 7·4 magnitude star 2^m following and about 1′·5 north which would be suitable for this comparison. The position-micrometer could be used with this star to measure the difference in declination.

Lick Observatory:
1891 *March* 24.

A Comparison of the North Polar Distances of the Nautical Almanac for 1880 *with the Cape Catalogue, the Greenwich Ten-year Catalogue, and Boss's Standard Star Places for* 1880. By W. Grasett Thackeray.

The following comparison was made for the purpose of seeing whether the Greenwich Ten-year Catalogue Star Places for 1880 would corroborate the results of a comparison between the *Nautical Almanac* and Cape General Catalogue for 1880, given by Mr. Stone in a paper published in the *Monthly Notices*, xl. 2, pp. 57–70.

In this paper it was shown that the discordances in N.P.D. (Cape–Greenwich), arranged for every six hours of R.A., gave the following corrections after applying the general mean correction of −0″·31:

0^h–6^h.	6^h–12^h.	12^h–18^h.	18^h–24^h.
−0″·24	−0″·11	+0″·39	+0″·06

and it was further remarked that the observations corresponding to the result grouped under 0^h–6^h were made during the dry

season at the Cape, and that the observations corresponding to the result grouped under 12^h–18^h were made during the wet season at the Cape. The conclusion, therefore, seemed to be that the discordances were systematic, and must be connected with the changes of temperature or moisture which take place at these different seasons at the Cape. From the present comparison it would appear that the discordances are not due to these causes.

(1) The comparison between the *Nautical Almanac* and the Cape Catalogue for 1880 has been taken from Mr. Stone's paper, mentioned above.

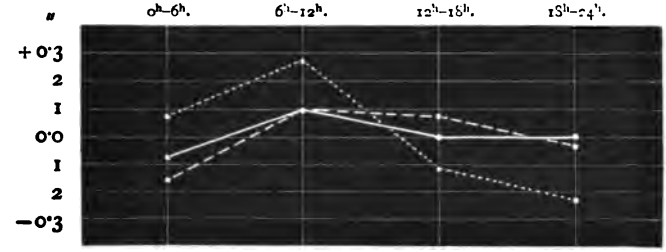
(2) The comparison between the Greenwich Ten-year Catalogue and the Cape Catalogue for 1880 depends only on the *Nautical Almanac* stars used in the above comparison. As the number of observations of each star in the Greenwich Catalogue is much greater than in the Cape Catalogue, the means were obtained by weighting the results according to the number of observations in the Cape Catalogue with a maximum weight of 10 to any one star; the results are found to be practically the same as if every star had had the same weight.

(3) (4) (5) Boss's standard star places were obtained by applying to the *American Nautical Almanac* star places for 1880 the corrections derived from the Appendix, Table VIII., equal weights being given to every star.

	0^h–6^h.	6^h–12^h.	12^h–18^h.	18^h–24^h.	Mean.
(1) *N. A.*, 1880–Cape ...	+″·55	+″·42	−″·08	+″·25	+″·31
(2) Greenwich–Cape (1880) (1880) ...	$+\cdot36_{43}$	$+\cdot52_{42}$	$+\cdot31_{35}$	$+\cdot42_{39}$	+·40
(3) Greenwich–Boss (1880) (1880) ...	$+\cdot30_{23}$	$+\cdot30_{21}$	$+\cdot20_{29}$	$+\cdot38_{22}$	+·30
(4) *N. A.*, 1880—Boss (1880) ...	$+\cdot40_{23}$	$+\cdot27_{21}$	$-\cdot12_{29}$	$+\cdot09_{22}$	+·16
(5) Cape, 1880–Boss ...	$-\cdot19_{26}$	$-\cdot28_{21}$	$-\cdot30_{29}$	$-\cdot04_{22}$	−·20

The subscribed figures denote the number of stars on which the results depend. Correcting each of these results for the mean error—

	0^h–6^h.	6^h–12^h.	12^h–18^h.	18^h–24^h.	
Greenwich, 1880–Boss ...	″·00	″·00	−″·10	+″·08	———
N. A., 1880–Boss	+·24	+·11	−·28	−·07	·····
Cape, 1880–Boss	+·01	−·08	−·10	+·16	·····
Greenwich, 1880–Cape, 1880	−·04	+·12	−·09	+·02	



The mean places of the stars in the *Nautical Almanac* for 1880 have been derived from the Greenwich Catalogues for 1860 and 1864, and for the stars not therein contained from the Cape Catalogue of 1,159 Stars, the first Melbourne General Catalogue, and the Cape Separate Catalogues 1871–3, and hence it would appear that the Greenwich Ten-year Catalogue places arranged in order of right ascension do not agree with those derived from the 1860 and 1864 Catalogues as given in the *N. A.*

The following comparison between the *N.A.* star places for 1880 and 1890 was made in order to compare the 1860, 1864, and 1872 Greenwich Catalogues together (the *N.A.* star places for 1890 depending on the 1872 Catalogue). The stars used in this comparison are those only which were used in Mr. Stone's paper, and the precession, secular variation, and proper motions have been taken from the Ten-year Catalogue.

The other two comparisons are obtained indirectly from the last and former comparisons.

	h h 0–6.	h h 6–12.	h h 12–18.	h h 18–24.	Mean.
N. A., 1880—*N. A.*, 1890	+″·13	″·00	+″·18	+″·12	+″·11
Greenwich Cat., 1880—*N. A.*, 1880	−·19	+·10	+·39	+·17	+·12
Greenwich Cat., 1880—*N. A.*, 1890	−·06	+·10	+·57	+·29	+·22

From these results it would appear that the Mean North Polar distances of stars in the *Nautical Almanacs* for 1880 and 1890, which are derived from the Greenwich Catalogues for 1860, 1864, and 1872, are liable to a periodic error when arranged in order of right ascension, and that this error (probably largely due to the differences of the adopted proper motions) has been eliminated in the Ten-year Catalogue for 1880.

Approximate Proper Motions of some Groombridge Stars.

By W. Grasett Thackeray.

The following Groombridge stars, which have been observed at Greenwich since 1876, and for which no proper motions are known to have been determined, were found to have proper motions either of at least ·01ˢ in right ascension or 0″·1 in north polar distance. The proper motions have been provision-

ally determined by taking the places as given in the Radcliffe Catalogue for 1845 for the Groombridge and Radcliffe observations, and by reducing the Greenwich observations back to the year 1845 by applying the secular variation to the precessions given in the ten-year or annual catalogues.

The results, which are only meant to call attention to the fact that the star-places are liable to sensible errors when brought up from some years back, have been given both from the comparison of the Groombridge and Radcliffe places, and of the Radcliffe and Greenwich places, and are not sufficiently accurate to be appreciably affected by the difference between Bessel's and Struve's precessions. The results are in many cases more accordant than might have been expected:—

Groombridge Nos.	Proper Motion in Right Ascension.		Proper Motion in North Polar Distance.		Groombridge Nos.	Proper Motion in Right Ascension.		Proper Motion in North Polar Distance.	
	Groombridge and Radcliffe.	Radcliffe and Greenwich.	Groombridge and Radcliffe.	Radcliffe and Greenwich.		Groombridge and Radcliffe.	Radcliffe and Greenwich.	Groombridge and Radcliffe.	Radcliffe and Greenwich.
	s	s	"	"		s	s	"	"
9	+·01	+·01	−·01	−·02	1775	−·01	...	−·11	−·12
11	+·01	+·01	+·06	...	1781	...	...	+·09	+·11
30	+·01	+·01	+·04	+·04	1930	+·02	+·02	−·01	+·01
145	+·08	+·01	+·24	+·25	1971	−·01	−·03	+·02	−·04
356	+·02	+·02	+·19	+·24	1972	−·02	−·02	+·04	−·04
628	+·02	+·01	+·03	+·01	2044	−·01	−·01	+·06	+·05
706	+·02	+·02	+·16	+·16	2089	...	...	+·10	+·13
717	−·01	−·01	+·08	+·16	2141	...	−·01	−·21	−·18
752	+·01	+·01	+·13	+·18	2196	+·14	+·09	+·26	+·23
757	...	−·01	−·08	−·13	2391	+·05	+·02	−·17	−·22
762	+·06	+·04	+·28	+·27	2527	+·02	+·01	−·21	−·29
828	...	...	+·15	+·09	2538	−·01	−·02	−·13	−·02
936	...	...	+·11	+·14	2571	−·02	−·03	−·21	−·23
1178	+·02	+·01	+·24	+·19	2580	+·01	+·01	−·12	−·19
1209	...	...	+·10	+·09	2867	+·01	+·01	−·32	−·33
1214	+·01	...	+·13	+·19	3249	+·01	...	+·16	+·26
1216	+·02	+·01	+·25	+·21	3263	...	...	−·19	−·19
1228	+·02	+·02	+·03	+·06	3295	+·01	+·02	+·13	+·17
1281	+·01	...	+·20	+·20	3409	−·01	−·01	+·17	+·09
1400	+·05	+·03	−·11	−·07	3636	+·02	+·02	−·09	−·07
1482	+·01	...	−·18	+·17	3703	+·02	+·01	−·05	−·04
1517	−·01	−·02	+·10	+·05	3882	+·02	+·02	−·06	+·01
1527	−·01	−·01	−·07	−·06	3904	+·02	+·02	−·12	−·07
1668	...	−·01	+·13	+·06	4177	...	−·01	−·24	−·24

The Perturbations of Sappho (80). By Robert Bryant, B.A., D.Sc.

The following values of the perturbations of *Sappho* form a continuation of those previously published by me. As previously, the elements have been corrected for the effect of perturbation every forty days. Great pressure of other matters has prevented me from preparing for the time of the opposition of this planet in 1889 an ephemeris such as will be required for the reduction of the observations for determining its parallax. I have partially revised my previous work on the orbit of this planet. Dr. Otto Knopf has pointed out to me errors in some of the normal places, in correcting some of which a better representation of the observations is obtained. I have also found minor mistakes in the calculation of the perturbations, which must be expected when one deals single-handed with three millions of figures; but these have no great effect upon the result. I have, however, detected an error of a more serious kind. In integrating the differentials from 1872 September 7, backwards, the element of time was regarded as positive, and the sign of the result was changed before applying the correction thus found to the elements, to obtain the effect of the terms depending upon the squares and higher powers of the masses of the disturbing bodies. The perturbation of the mean longitude consists of two parts, one of which is that arising from a change in the mean motion, and depends upon a double integral, and consequently the sign of the result in this case should have been left unchanged. Unfortunately the effect of this error of sign is such that (so far as this element is concerned) the result is less accurate than if the correction had been omitted altogether.

Disturbing Action of Venus.

1888.	ΔL_1.	ΔL_2.	$\Delta\pi$.	$\Delta\Omega$.	Δi.	$\Delta\phi$.	$40\,\Delta\mu$.
Apr. 16	+0″·77	+ 0″·08	− 3″·14	+0″·15	−0″·10	−0″·31	−0″·176
May 6	0·00	0·00	0·00	0 00	0·00	0·00	0·000
26	−1·03	+ 0·05	+ 2·40	−0·06	+0·05	−0·13	+0·077
June 15	−2·06	+ 0·12	+ 3·15	−0·06	+0·05	−0·63	+0·036
July 5	−2·85	+ 0·08	+ 1·80	−0·06	−0·02	−1·33	−0·118
25	−3·17	− 0·15	− 1·48	−0·12	−0·12	−1·99	−0·355
Aug. 14	−2·96	− 0·64	− 5·85	−0·23	−0·22	−2·41	−0·625
Sept. 3	−2·23	− 1·39	−10·11	−0·36	−0·30	−2·44	−0·865
23	−1·14	− 2·34	−13·09	−0·41	−0·32	−2·11	−1·029
Oct. 13	+0·06	− 3·41	−14·04	−0·34	−0·30	−1·56	−1·083
Nov. 2	+1·13	− 4·47	−12·69	−0·10	−0·24	−0·97	−1·016
22	+1·89	− 5·40	− 9·31	+0·26	−0·16	−0·55	−0·833
Dec. 12	+2·21	− 6·11	− 4·74	+0·64	−0·10	−0·41	−0·569

1889.	ΔL_1.	ΔL_2.	$\Delta\pi$.	$\Delta\Omega$.	Δi.	$\Delta\phi$.	$40\,\Delta\mu$.
Jan. 1	+2″09	− 6·53	− 0·19	+0″91	−0″06	−0″61	−0″275
21	+1·56	− 6·67	+ 3·16	+0·95	−0·05	−1·05	−0·016
Feb. 10	+0·77	− 6·59	+ 4·43	+0·71	−0·07	−1·58	+0·150
Mar. 2	−0·11	− 6·42	+ 3·38	+0·23	−0·10	−1·99	+0·178
22	−0·87	− 6·29	+ 0·44	−0·34	−0·13	−2·10	+0·057
Apr. 11	−1·37	− 6·34	− 3·29	−0·82	−0·14	−1·81	−0·192
May 1	−1·49	− 6·69	− 6·90	−1·04	−0·15	−1·17	−0·519
21	−1·20	− 7·38	− 9·04	−0·94	−0·15	−0·32	−0·854
June 10	−0·52	− 8·38	− 9·22	−0·64	−0·16	+0·51	−1·131
30	+0·48	− 9·61	− 7·42	−0·25	−0·18	+1·12	−1·301
July 20	+1·68	−10·94	− 4·28	+0·10	−0·21	+1·39	−1·348
Aug. 9	+2·81	−12·26	− 0·93	+0·34	−0·24	+1·24	−1·268
29	+3·68	−13·44	+ 1·57	+0·41	−0·25	+0·67	−1·060
Sept. 18	+4·20	−14·35	+ 2·52	+0·31	−0·22	−0·21	−0·749
Oct. 8	+4·31	−14·93	+ 1·67	+0·13	−0·17	−1·13	−0·401
28	+4·03	−15·16	− 0·66	−0·03	−0·09	−1·86	−0·089
Nov. 17	+3·44	−15·14	− 3·64	−0·11	−0·02	−2·25	+0·125
Dec. 7	+2·64	−14·96	− 6·16	−0·13	+0·02	−2·22	+0·200

Disturbing Action of the Earth.

1888.	ΔL_1.	ΔL_2.	$\Delta\pi$.	$\Delta\Omega$.	Δi.	$\Delta\phi$.	$40\,\Delta\mu$.
Feb. 16	−3″36	−0″11	+ 7″37	−0″23	+0″08	−0″20	+0″176
Mar. 27	−1·82	−0·01	+ 3·28	−0·03	+0·01	−0·42	+0·034
May 6	0·00	0·00	0·00	0·00	0·00	0·00	0·000
June 15	+1·47	+0·04	− 0·83	−0·03	+0·04	+0·79	+0·090
July 25	+2·34	+0·23	+ 1·40	0·00	+0·12	+1·65	+0·300
Sept. 3	+2·55	+0·67	+ 5·87	+0·12	+0·21	+2·24	+0·588
Oct. 13	+2·13	+1·41	+10·85	+0·25	+0·26	+2·36	+0·885
Nov. 22	+1·25	+2·41	+14·26	+0·23	+0·26	+2·00	+1·106
1889.							
Jan. 1	+0·17	+3·56	+14·52	−0·04	+0·21	+1·46	+1·177
Feb. 10	−0·81	+4·69	+11·57	−0·50	+0·17	+1·13	+1·061
Mar. 22	−1·36	+5·61	+ 6·97	−0·91	+0·14	+1·31	+0·783
May 1	−1·44	+6·22	+ 2·94	−1·04	+0·14	+2·00	+0·417
June 10	−1·01	+6·45	+ 1·22	−0·89	+0·13	+2·96	+0·056
July 20	−0·09	+6·37	+ 2·58	−0·63	+0·11	+3·77	−0·205
Aug. 29	+1·41	+6·12	+ 6·74	−0·52	+0·10	+4·05	−0·290
Oct. 8	+3·61	+5·85	+12·78	−0·58	+0·12	+3·69	−0·227
Nov. 17	+5·84	+5·66	+18·35	−0·61	+0·12	+3·09	−0·171
Dec. 27	+7·33	+5·59	+20·11	−0·60	+0·15	+2·22	+0·024

Disturbing Action of Mars.

	ΔL_1.	ΔL_2.	$\Delta\pi$.	$\Delta\Omega$.	Δi.	$\Delta\phi$.	$40\,\Delta\mu$.
1888.	"	"	"	"	"	"	"
Feb. 16	−0·37	−0·01	+0·69	+0·02	−0·01	−0·08	+0·004
Mar. 27	−0·19	0·00	+0·38	+0·01	0·00	−0·04	+0·005
May 6	0·00	0·00	0·00	0·00	0·00	0·00	0·000
June 15	+0·18	−0·01	−0·36	0·00	0·00	+0·03	−0·010
July 25	+0·31	−0·02	−0·63	0·00	0·00	+0·07	−0·018
Sept. 3	+0·42	−0·04	−0·73	0·00	0·00	+0·12	−0·021
Oct. 13	+0·50	−0·06	−0·68	+0·01	0·00	+0·16	−0·017
Nov. 22	+0·56	−0·07	−0·49	+0·03	+0·01	+0·20	−0·007
1889.							
Jan. 1	+0·60	−0·07	−0·23	+0·05	+0·01	+0·21	+0·007
Feb. 10	+0·62	−0·06	+0·06	+0·06	+0·01	+0·21	+0·025
Mar. 22	+0·63	−0·02	+0·31	+0·07	+0·01	+0·18	+0·043
May 1	+0·63	+0·03	+0·49	+0·07	+0·01	+0·15	+0·061
June 10	+0·62	+0·10	+0·60	+0·05	+0·01	+0·11	+0·077
July 20	+0·61	+0·18	+0·64	+0·04	+0·01	+0·07	+0·092
Aug. 29	+0·60	+0·28	+0·63	+0·02	+0·01	+0·03	+0·106
Oct. 8	+0·59	+0·39	+0·56	+0·01	+0·02	0·00	+0·119
Nov. 17	+0·57	+0·52	+0·45	0·00	+0·02	−0·03	+0·131
Dec. 27	+0·56	+0·66	+0·31	0·00	+0·02	−0·05	+0·142

Disturbing Action of Jupiter.

1888.	ΔL_1.	ΔL_2.	$\Delta\pi$.	$\Delta\Omega$.	Δi.	$\Delta\phi$.	$40\,\Delta\mu$.
	"	"	"	"	"	"	"
Feb. 16	+ 7·42	− 9·79	+ 76·39	− 2·57	+ 1·23	+ 35·52	+ 9·461
Mar. 27	+ 6·24	− 2·52	+ 42·92	− 1·32	+ 0·77	+ 18·63	+ 4·993
May 6	0·00	0·00	0·00	0·00	0·00	0·00	0·000
June 15	− 12·43	− 2·61	− 50·57	+ 0·85	− 1·18	− 19·66	− 5·211
July 25	− 31·70	− 10·34	− 103·80	+ 0·37	− 2·82	− 39·36	− 10·122
Sept. 3	− 57·38	− 22·49	− 150·87	− 2·44	− 4·89	− 58·17	− 14·003
Oct. 13	− 87·36	− 37·68	− 180·57	− 8·43	− 7·20	− 75·28	− 16·034
Nov. 22	− 117·86	− 53·75	− 183·85	− 17·66	− 9·45	− 90·60	− 15·619
1889.							
Jan. 1	− 144·39	− 68·11	− 159·41	− 29·10	− 11·31	− 104·59	− 12·752
Feb. 10	− 163·67	− 78·65	− 115·60	− 40·89	− 12·56	− 117·80	− 8·127
Mar. 22	− 174·66	− 84·11	− 66·10	− 51·16	− 13·18	− 130·19	− 2·861
May 1	− 178·47	− 84·53	− 22·87	− 58·76	− 13·34	− 141·01	+ 1·954
June 10	− 177·32	− 80·66	+ 8·46	− 63·43	− 13·24	− 149·25	+ 5·574
July 20	− 173·53	− 73·79	+ 28·75	− 65·63	− 13·10	− 154·18	+ 7·673
Aug. 29	− 168·95	− 65·82	+ 42·85	− 66·13	− 13·04	− 155·64	+ 8·267
Oct. 8	− 164·90	− 57·78	+ 56·21	− 65·80	− 13·13	− 154·27	+ 7·632
Nov. 17	− 162·18	− 50·84	+ 72·45	− 65·40	− 13·39	− 151·01	+ 6·136
Dec. 27	− 161·20	− 45·68	+ 92·71	− 65·54	− 13·78	− 146·92	+ 4·152

Disturbing Action of Saturn.

1888.	ΔL_1.	ΔL_2.	$\Delta\pi$.	$\Delta\Omega$	Δi.	$\Delta\phi$.	$40\,\Delta\mu$.
	"	"	"	"	"	"	"
Feb. 16	−1·00	−0·08	+ 1·29	+0·08	−0·03	−0·48	−0·057
Mar. 27	−0·50	−0·01	+ 0·74	+0·01	−0·01	−0·18	−0·008
May 6	0·00	0·00	0·00	0·00	0·00	0·00	0·000
June 15	+0·45	−0·01	− 1·00	0·00	−0·01	+0·08	−0·030
July 25	+0·83	−0·07	− 2·32	0·00	−0·02	+0·09	−0·094
Sept. 3	+1·09	−0·21	− 3·93	−0·04	−0·05	+0·05	−0·185
Oct. 13	+1·23	−0·45	− 5·80	−0·12	−0·08	0·00	−0·295
Nov. 22	+1·24	−0·80	− 7·82	−0·26	−0·11	−0·04	−0·415
1889.							
Jan. 1	+1·12	−1·28	− 9·86	−0·45	−0·15	−0·07	−0·535
Feb. 10	+0·88	−1·87	−11·76	−0·70	−0·17	−0·08	−0·642
Mar. 22	+0·56	−2·55	−13·40	−0·99	−0·19	−0·09	−0·723
May 1	+0·19	−3·30	−14·70	−1·29	−0·20	−0·14	−0·768
June 10	−0·20	−4·07	−15·67	−1·57	−0·19	−0·24	−0·766
July 20	−0·55	−4·81	−16·42	−1·82	−0·17	−0·42	−0·716
Aug. 29	−0·82	−5·48	−17·11	−2·01	−0·15	−0·69	−0·623
Oct. 8	−0·97	−6·05	−17·86	−2·13	−0·12	−1·00	−0·505
Nov. 17	−0·98	−6·49	−18·63	−2·18	−0·09	−1·30	−0·382
Dec. 27	−0·87	−6·83	−19·26	−2·17	−0·07	−1·56	−0·281

The above values are for Greenwich mean noon.

Reduction of Measures of the Photographs of Jupiter taken at the Lick Observatory in 1890. By A. Stanley Williams.

Through the kindness of Professor E. S. Holden, I have recently been favoured with particulars of an important series of measurements of the belts of *Jupiter*, made by him on the remarkably fine series of photographs of the planet which he obtained last year by means of the great Lick refractor. These measures furnished on reduction the zenographical latitudes of the principal belts; and, as the results are interesting in more ways than one, I herewith beg to present them to the Society.

The photographs measured were enlarged directly in the telescope 8·3 times, the image of the planet on the plates taken at about the time of opposition being very nearly an inch in diameter. The distances were measured by Professor Holden in millimetres from the north pole to the middle points of the chief belts, and the minor axis of the disc was also measured on each plate. In order to show clearly the method of reduction em-

ployed in the present case, the details are given fully below for one of the belts—namely, the dark belt No. 6:

Date.	G.M.T. of Photograph.	Minor Axis.	Dist. from N. Pole.	Dist. from Centre of Disc.	Corresponding Latitude.	Correction B.	True Zenographical Latitude.
1890.	h m	mm.	mm.		°	°	°
July 8	21 3	21·5	16·0	−·488	−27·64	−·27	−27·91
13	21 13	21·6	16·0	·482	27·27	·28	27·55
Aug. 31	18 25	21·2	15·5	·462	26·01	·38	26·39
Sept. 1	18 3½	21·1	15·5	·469	26·45	·38	26·83
8	18 9	20·7	15·5	·498	28·28	·40	28·68
14	17 14	20·3	15+	(·478)	27·01	·41	(27·42)
Oct. 19	15 17	18·4	13·9	·511	29·11	·42	29·53
19	15 29	...	13·7	·489	27·71	·42	28·13
27	15 10	18·0	13·0	−·444	−24·90	−·41	−25·31

The first four columns of the above table sufficiently explain themselves. The fifth gives the distance from the centre of the disc, where the semi-axis minor = 1; and the sixth the corresponding latitude according to Dr. Lohse's useful little table, published in "Publicationen des Astrophysikalischen Observatoriums zu Potsdam," No. 9, p. 7. Column 7 contains the corrections to be added to the preceding latitudes, arising from the elevation of the Earth above the plane of *Jupiter's* equator. They are taken from Mr. Marth's invaluable "Ephemeris for Physical Observations of *Jupiter*" in the *Monthly Notices*. Finally, in the last column are the true zenographical latitudes. The mean position of the middle of the belt No. 6, from the measurements of eight plates, is −27°·54, with a probable error of ±0°·32. The observation of September 14 is rejected for obvious reasons.

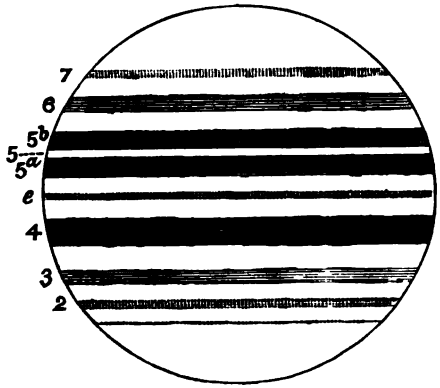
The measures relating to the other belts have been reduced in an exactly similar manner to the above. With one exception, where it is doubtful what was the exact part of the belt measured, all the measures have been made use of, though in some cases, by rejecting one or two of them, the separate results might be made a good deal more accordant and the probable errors of the final determinations smaller, the latitudes of some of the belts evidently varying a little in different parts of the planet. Belt No. 6 may be instanced as an example of this. The last measure (October 27) relates to the part just preceding the red spot, and the belt here was at that time clearly more northerly than at other parts.* A measure of the first plate of October 19, giving a latitude of −17°·68, has not been made use of, the middle of

* This belt was also considerably broader at some parts of the planet than at others, which circumstance must doubtless have affected the measures.

the bright zone south of the dark south equatorial belt having evidently been inadvertently measured, instead of the middle of the latter belt. The final resulting positions of the middle points of the principal belts are given in the following table :—

Belt.	Mean Latitude.	Dist. from Centre.	No. of Plates.
7	$-38°.45$	$-.647$	1
6	-27.54 ± 0.32	$-.486$	8
$5b$	-15.45 ± 0.07	$-.283$	3
5	-11.80 ± 0.19	$-.218$	11
$5a$	-8.23 ± 0.24	$-.153$	5
e	$+0.21 \pm 0.10$	$+.004$	18
4	$+10.37 \pm 0.17$	$+.192$	18
3	$+24.55 \pm 0.12$	$+.438$	18
2	$+33.35 \pm 0.55$	$+.575$	3
	Red Spot.		
S. edge...	$-28°.00$	$-.494$	1
Centre (apparent) ...	-20.53	$-.371$	1
N. edge	-13.51	$-.249$	1

The distances from the centre are those corresponding to the latitudes given in the second column, or when the elevation of the Earth above the plane of *Jupiter's* equator is nil. Belt No. 5 is the south equatorial belt. It is actually double, being composed of two parallel dark bands, separated by a narrow bright rift, and this duplex character is shown very clearly on several of the Lick photographs. $5a$ refers to the northern and $5b$ to the southern component of this double belt. By means of the distances from the centre given above, the positions of the belts have been laid down in the diagram.



On one plate, dated September 21, the outside dimensions of the red spot were measured by Professor Holden as follows: Length, $6{\cdot}6^{mm}$; breadth, $2{\cdot}4^{mm}$; distance from E. end to limb, $6{\cdot}0^{mm}$; distance from W. end to limb, $6{\cdot}3^{mm}$. According to these measures the photograph was obtained $1{\cdot}6^{m}$ before the centre of the red spot had arrived on the central meridian of the disc. The photograph was taken at either $16^{h}\ 8^{m}$ *or* $16^{h}\ 10^{m}$ G.M.T. Assuming the mean of these to be correct, the spot would have transited at $16^{h}\ 10{\cdot}6^{m}$ G.M.T.; and the centre consequently preceded the zero meridian of Mr. Marth's ephemeris (System II.) by $8{\cdot}2^{m}$. Visual observations make the difference somewhat greater. From observations by the writer the spot at that time preceded the zero meridian by about 15^{m}.

Measures of the position of a small dark spot on the north side of the N. equatorial belt were also made on two photographs taken on July 13. These give for the time of the transit of the spot over the central meridian of the disc, $21^{h}\ 24{\cdot}7^{m}$ G.M.T. from one plate, and $21^{h}\ 28{\cdot}1^{m}$ from the other. The mean of these two determinations, $21^{h}\ 26{\cdot}4^{m}$, agrees well with visual observations made about the same time, as will be seen from the following list of transits:—

1890.	G.M.T. of Transit.	Foll. Mr. Marth's Zero Mer. System II. by	
	h m	h m	
June 26	12 35·3	2 52·7	Williams, visual
July 3	13 16·3	2 48·7	,, ,,
13	21 26·4	2 49·1	Holden, photo.
22	13 48·2	2 43·7	Williams, visual
Aug. 1	12 4·0	2 45·3	,, ,,
2	17 49·5	2 44·1	Barnard*, visual
4	9 31·7	2 43·9	Williams, visual

As there are many measurable dark and light spots shown on the Lick photographs of *Jupiter* in the possession of the Society, suitable measures of this magnificent collection should form a valuable addition to the results obtained directly at the telescope.

It would be interesting to compare the positions of the belts given in this paper with corresponding results obtained by micrometrical measures at the telescope, particularly with the view of ascertaining the relative degree of accuracy of the two methods. Unfortunately, however, it is seldom possible to make a satisfactory comparison, since, although many series of micrometer measures have been made, the results have rarely been fully reduced. The points measured also are not always the same, some observers having measured the edges of the principal belts, and others the middle points of the bands, whilst in some cases it does not clearly appear what was the part measured.

* *Publications of the Astronomical Society of the Pacific*, vol. ii. p. 248.

Belt No. 3 was measured by Dr. O. Lohse, at Potsdam, on four nights in 1879. These measures I have reduced in the same manner as Belt No. 6, *supra*. The same belt was also measured by me in 1888 on three nights, and in 1890 on one night, so that we have the following results :—

Latitude of Belt No. 3.

1879	$+20^{\circ}32 \pm 0^{\circ}19$	Lohse (4 nights), micrometric
1888	$+25^{\circ}36 \pm 0^{\circ}38$	Williams (3 nights), micrometric
1890	$+24^{\circ}55 \pm 0^{\circ}12$	Holden (18 plates), photographic
1890	$+24^{\circ}52$	Williams (1 night), micrometric

These measures show that a very considerable displacement must have occurred in the place of this belt. From the measures of the position of the red spot made by him on nine nights in 1879–81, Dr. Lohse found the mean latitude to be $-21^{\circ}52$, with a probable error of $\pm 0^{\circ}25$*. The latitude being approximately the same as that of Belt 3, this is fairly comparable with the others, so far as regards the probable accuracy of the result.

It would appear from consideration of the probable errors in the above cases, and also from comparison of the agreement *inter se* between the individual results of Dr. Lohse's measures, and between the separate determinations of Professor Holden, that measures of photographs of *Jupiter*, in their present state of perfection, are equal in point of accuracy to the best micrometrical measures; whilst not the least of the advantages of the former method is the power of being able to make the measures at one's leisure, and to repeat them if necessary, or to supplement them by measures of fresh points, so as to be able strictly to compare the positions of objects with the results obtained in previous years.

* *Publicationen des Astrophysikalischen Observatoriums zu Potsdam*, No. 9, p. 18. No correction seems to have been applied for elevation of the Earth above the plane of *Jupiter's* equator, so that the probable error is here probably larger than it would otherwise be. As this correction may exceed 3°, it is very important that it should not be neglected, or otherwise the results of one year may differ by more than 6° from those of another year. 6° of zenographical latitude near the equator is equivalent to more than 2″·2 of arc, when the apparent diameter of the planet is 40″.

Catalogue of 918 *Orbits of Meteor Streams from the Observations of Mr. W. F. Denning.* By J. Kleiber.

(Abstract.)

The following pages contain a catalogue of orbits of meteor-showers,* corresponding to the 918 radiant points given by Mr. W. F. Denning in the May number of the *Monthly Notices* for 1890.

The 918 radiants or orbits represent in reality a much smaller number of distinct streams, many streams being represented by more than one radiant. But as the identification of radiants is a matter still subject to controversy, I found it better to compute the elements for each radiant separately, giving thus a new criterion for their identification *à posteriori* by comparing the elements of their orbits.

The computation has been effected by means of special tables constructed *ad hoc*, which permitted to find directly all the elements *without neglecting the eccentricity of the Earth's orbit.* I retained in the course of the calculation tenths of a degree, rejecting these only in the final result, where I put ½ for 0·3, 0·4, 0·5, 0·6, 0·7, and 1 for 0·8, 0·9, 1·0, 1·1, 1·2.

I may add, as a first preliminary result of my computation, that it confirms the shifting of the radiant of the *Perseids* during the six weeks of the activity of the shower, as observed by Mr. W. F. Denning. A glance at the orbits corresponding to all the radiants related by Mr. Denning to the *Perseid* shower, will show their identity at once.

In the catalogue the number is that of Mr. Denning's list: l, b denote the longitude and latitude of the radiant respectively, Ω, i, $\pi-\Omega$, and q are the usual parabolic elements of the orbit corresponding to the radiant.

St. Petersburg:
1891 *January* 12.

Sur la Détermination récente de la Longitude Paris–Greenwich. Par MM. Bassot et Defforges.

(*Communicated by H. H. Turner, M.A., B.Sc.*)

Voulez-vous nous permettre d'ajouter quelques considérations à celles qu'a déjà développées devant la société monsieur H.-H. Turner sur les résultats de la mesure de la différence de longitude entre Paris et Greenwich, en 1888?

Il existe en effet entre monsieur Turner et nous-mêmes quelques différences d'appréciation, et comme il nous a très-loyalement priés de rendre notre opinion publique et gracieusement offert de la présenter à la Société Royale Astronomique,

* Extracted from a book now in the press, *On the Determination of Orbits of Meteor Showers* (in Russian).

nous vous demandons de vouloir bien accueillir ces quelques réflexions qui vous sont adressées par son intermédiaire.

Les valeurs individuelles obtenues pour la différence de longitude entre Paris (méridien de Cassini) et Greenwich (méridien du Transit-Circle) sont contenues dans le tableau suivant.

TABLEAU I.

Valeurs individuelles de la Différence de Longitude entre Paris et Greenwich.

Dates.	Échanges H T et L.	Échanges B et D.	Échanges H T et D.	Échanges B et L.
	9^m s	9^m s	9^m s	9^m s
Sept. 30	20·73	20·85	21·10	20·47
Oct. 1	20·77	20·89	21·12	20·56
3	20·98	20·99	21·19	20·72
5	20·97	20·91	21·14	20·73
11	20·65	21·17	20·81	21·05
13	20·69	21·18	20·64	21·24
14	20·72	21·25	20·71	21·26
15	„	„	20·88	„
17	20·73	21·20	20·84	21·14
19	20·54	21·18	20·82	20·96
20	20·60	21·22	20·82	20·98
21	20·62	21·10	20·72	21·02
23	21·30	20·97	21·32	20·96
26	21·07	20·84	21·07	20·72
27	21·19	„	„	„
30	21·12	20·95	21·23	20·89
Nov. 9	21·18	21·00	21·42	„
13	21·02	20·84	21·16	20·67
Moyennes 1re période ...	20·86	20·91	21·14	20·62
Moyennes 2e „ ...	20·65	21·19	20·78	21·09
Moyennes 3e „ ...	21·15	20·92	21·24	20·81
1re et 2e périodes ...	20·76	21·05	20·96	20·86
2e et 3e „ ...	20·90	21·06	21·01	20·95
Longitude moyenne ...	20·83	21·06	20·99	20·91

La comparaison des résultats moyens des 3 périodes fournit pour les valeurs des équations personnelles :

	H T−L. s	B−D. s	H T−D. s	B−L. s
1er Échange d'observateurs	−0·10	+0·14	−0·18	+0·23
2e „ „	−0·25	+0·14	−0·23	+0·14
Moyennes	−0·18	+0·14	−0·21	+0·19

L'équation personnelle B—D est restée remarquablement constante ; elle est d'ailleurs identique à la moyenne des valeurs déterminées, presque chaque année, depuis 1877, c'est-à-dire depuis 14 ans, entre les deux observateurs B et D.

Mais les différences des deux valeurs de chacune des équations B—L et HT—L semblent indiquer chez l'observateur L une variation d'équation personnelle assez notable.

La différence des équations personnelles moyennes deux à deux donne :

$$B-HT = +0^{s}.37$$
$$B-HT = +0^{s}.35$$

L'accord de ces 2 valeurs montre que l'influence des erreurs systématiques des quatre chronographes pendant les échanges est très petite et peut être négligée. Les divergences des valeurs trouvées pour la longitude n'en peuvent donc provenir.

Dans le but d'en rechercher l'origine, on a fait intervenir l'observateur "Standard" de Greenwich (AD). La pendule "Standard" de l'observatoire de Greenwich enregistrait, par l'intermédiaire d'un relai distributeur, intercalé dans le circuit de l'observatoire, la seconde sidérale sur les deux chronographes de la longitude. La correction de cette pendule, donnée par AD, a été comparée chaque jour aux corrections trouvées par les deux observateurs de Greenwich.

On a obtenu, par cette comparaison, les nombres suivants :

Tableau II.

Dates.	AD—HT.	AD—B.	AD—L.	AD—D.
	s	s	s	s
Sept. 30	...	...	−0·16	+0·23
Oct. 1	...	...	0	+0·37
3	...	...	+0·08	+0·32
5	...	...	+0·24	+0·42
11	−0·12	+0·29	...	...
13	−0·23	+0·37	...	...
14	−0·07	+0·45	...	...
15	+0·03	„	...	...
17	−0·04	+0·33	...	...
20	−0·05	+0·31	...	...
21	+0·04	+0·44	...	...
23	...	...	+0·49	+0·47
26	...	...	−0·07	0
27	...	...	+0·15	„
30	...	...	+0·38	+0·46
Nov. 9	...	..	+0·12	+0·42
13	...	...	+0·11	+0·26
Moyennes...	−0·06	+0·37	+0·13	+0·33

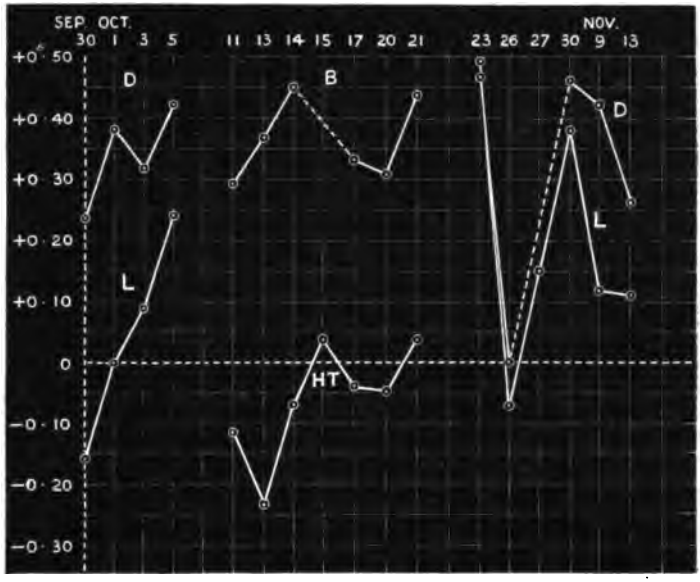
Prenant les moyennes de ces nombres pour chaque observateur comme la mesure de son équation personnelle avec A D, on a calculé au moyen des échanges de signaux enregistrés sur les chronographes la valeur de la longitude par la comparaison des heures observées d'une part à Greenwich par A D, et d'autre part à Paris successivement par H T, L, B et D. On a trouvé :

TABLEAU III.

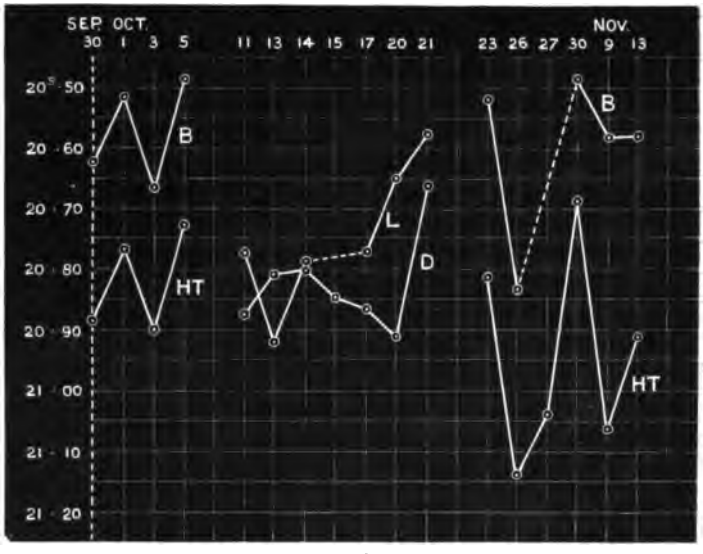
Dates.	Longitudes déterminées par			
	H T et A D.	B et A D.	L et A D.	D et A D.
Sept. 30	20·89	20·62	...	...
Oct. 1	20·77	20·52	...	...
3	20·90	20·67	...	...
5	20·73	20·49	...	...
11	...	...	20·77	20·88
13	...	...	20·92	20·81
14	...	...	20·79	20·80
15	...	...	„	20·85
17	...	...	20 77	20·87
20	...	...	20 65	20·91
21	...	...	20·58	20·66
23	20·81	20·52	...	...
26	21·14	20·84	...	...
27	21·04	„	...	...
30	20·74	20·49	...	...
Nov. 9	21·06	20·58	...	...
13	20 91	20 58	...	...
Moyennes.	20·90	20·59	20·75	20 83
Equations personnelles	− 0·06	+ 0·37	+ 0·13	+ 0·33
Longitude conclue ...	20·84	21·96	20·88	21·16

C'est ainsi que H T et L paraissent s'accorder entre eux et que D et B semblent diverger de $0^s·2$.

En examinant de plus près les deux tableaux précédents, nous avons été conduits à construire les diagrammes représentant d'une part les équations personnelles, calculées comme ci-dessus, des observateurs de Greenwich avec A D, de l'autre les valeurs qui en sont déduites pour la longitude. Ces diagrammes sont figurés ci-contre.



Courbes des Equations personelles avec A D (Standard Observer).



Longitudes (Standard Observer).

Ils affectent une allure remarquablement parallèle, et les quatre ordonnées présentent à la fois les mêmes variations

systématiques, variations qui atteignent jusqu'à $0^{s}.55$ d'un jour à l'autre.

Il n'y a, à notre avis, que deux manières d'expliquer ces variations.

Ou bien elles proviennent des variations mêmes de l'observateur AD, ce qui n'est admissible pour personne ; ou bien elles proviennent de la variation journalière accidentelle d'un organe intercalé entre la pendule de Greenwich et les chronographes, et cet organe n'est autre que le relai distributeur qu'il a fallu régler chaque jour et dont l'influence a par suite chaque jour été différente, comme on s'en convainc facilement d'ailleurs en examinant les variations inadmissibles des nombres contenus dans les tableaux II et III.

Cela étant, le calcul précédent n'est plus légitime, car l'équation personnelle moyenne déterminée par rapport à AD pour un observateur, pendant son séjour à Greenwich, renferme un élément variable indépendant de l'observateur, et ne peut lui convenir lorsqu'il s'est transporté à Paris.

L'équation personnelle réelle de AD avec l'observateur de Paris (HT, B, L, D) peut être cependant calculée pour chaque jour en ajoutant à l'équation du jour avec AD de l'observateur de Greenwich (L, D, HT, B) l'équation personnelle HT−L, B−D, B−L, HT−D.

Comparant de cette façon l'heure déterminée par AD à Greenwich avec l'heure déterminée à Paris, on trouverait :

TABLEAU IV.

Dates.		Longitudes déterminées avec A D.			
		par H T.	par B.	par L.	par D.
Sept.	30	20·55	20·99	...	...
Oct.	1	20·59	20·03	...	...
	3	20·80	21·13	...	...
	5	20·79	21·05	...	...
Moyennes		**20·68**	**21·05**	...	...
	11	...	...	20·83	21·03
	13	...	...	20·87	21·04
	14	...	...	20·90	21·11
	15	...	...	,,	,,
	17	...	...	20·91	21·06
	19	...	...	20·72	21·04
	20	...	...	20·78	21·08
	21	...	...	20·80	21·06
Moyennes		...	...	**20·83**	**21·06**
	23	21·12	21·11	...	...
	26	20 89	20·98	...	...
	27	21·01	,,	...	...
	30	20·94	21·09	...	...
Nov.	9	21·00	21·14	...	...
	13	20·84	20·98	...	...
Moyennes		**20·97**	**21·06**	...	...

L'écart entre les valeurs françaises et anglaises subsiste, mais les nombres moyens de B et D sont identiques, une fois l'influence du relai éliminée, tandis que la variation d'équation personnelle de L est de nouveau mise en évidence et fait croître à chaque période les nombres obtenus par H T et L.

Ce sont maintenant les valeurs françaises qui s'accordent entre elles, tandis que les nombres anglais sont discordants. Un tel résultat suffit pour enlever toute confiance aussi bien dans l'une que dans l'autre des valeurs de la longitude. Comme l'a fort bien dit l'astronome royal, il est nécessaire de recommencer la mesure et le plus tôt sera le mieux.

Il faudra, dans une nouvelle détermination, supprimer le relai distributeur, donner à chaque chronographe une pendule séparée, et surtout s'efforcer de s'affranchir des erreurs instrumentales (telles que : mouvements des objectifs, irrégularités des fioles des niveaux et flexions anormales), qui se sont manifestées, tant dans les instruments anglais que dans l'instrument français de Greenwich. Il y aurait, croyons-nous, une garantie sérieuse à échanger les instruments comme les observateurs. Il faut encore noter, comme l'a fait monsieur Turner dans l'Observatory, que les deux seules longitudes faites parallèlement et simultanément par deux couples d'observateurs différents ont donné toutes deux des résultats discordants. Peut-être la précision qu'on est habitué à attribuer aux longitudes télégraphiques n'est elle pas réelle. Les fermetures des polygones jusqu'à présent publiées tendraient à le faire supposer.

On the recent Determination of the Longitude Paris–Greenwich. Reply to Colonel Bassot and Commandant Defforges. By H. H. Turner, M.A., B.Sc.

In my last paper (*Monthly Notices*, vol. li. No. 3, page 155) I pointed out that the independent determinations of the longitude Paris–Greenwich in 1888 by English and French observers did not agree, the original discordance amounting to nearly $0^s.4$. I indicated my opinion that the determinations of level-error by the French observers at Greenwich with a striding level were, in some unexplained way, erroneous, and their determinations by reflexion observations from mercury were correct; on which supposition the value obtained for the longitude by the French observers would be in fair agreement with the English result. And I further appealed to the transit-circle observations at Greenwich to confirm this view.

I was aware that these opinions are not shared by the French observers, and should have added a statement of their views had I not hoped that they would make a direct communication on the subject, either in the publications of this Society or elsewhere. And I have now to thank them for the frankness with which they have stated their objections to my reasoning, and for

the honour they have done me in asking me to communicate the paper to the Society. The longitude Paris–Greenwich is one of such importance, and its determination was undertaken with such care and labour, that it seems to me imperative that any points at issue in connection with it should be clearly stated while yet they are fresh in the minds of those familiar with the work, in order that corresponding precautions may be taken in the future. And accordingly I do not hesitate to give in reply to the foregoing paper the reasons why I personally cannot accept the arguments therein contained.

These arguments are briefly as follow:—

(1) A comparison of personal equations shows that those of the French observers remained satisfactorily constant, while those of the English observers changed. This, as far as it goes, points to a greater accuracy in the French result.

(2) The daily results for time-determination at Greenwich, which I have compared with those obtained with the transit circle, differ so irregularly from the latter as to suggest a systematic error.

(3) Further, this systematic error may be localised in the relay interposed in the clock-circuit at Greenwich in order to convert make-signals into break-signals (to suit the French chronographs kindly lent for the occasion).

(4) Hence this comparison with the transit circle must be rejected, and we have thus no method of choosing between the two discordant results for longitude except that indicated in (1). The work must thus be done over again.

My reply to these paragraphs, in order, is as follows:—

(1) It is perfectly true that the personal equations of the English observers changed, as was very likely to happen in using small instruments for the first time, instead of the transit circle to which they were accustomed. But, owing to the special arrangements made for eliminating the effect of any such change, by a double interchange of observers, the effect on the longitude must be very small—far too small to explain any discordance such as is under consideration. Further, the accordance of the personal equations of the French observers with previous values proves nothing as to the accuracy of the longitude. The personal equations would have come out just as well if they had by some mistake observed a longitude any number of seconds, or minutes, or hours in error; that is to say, a systematic error in time-determination at one end of the line alters the longitude but not the personal equation.

Perhaps, however, the French observers may be referring more particularly to the suggestion in the last paragraph of my former paper—viz. that the error in level-determination to which I attribute the whole discordance was of such a nature as to affect the observations of B differently from those of D; and in this case they quite rightly point to the personal equations as evidence against this supposition. I should like to say one

or two words in examination of this point. In a letter to me dated 1891 February 5 Commt. Defforges says :—

"Le Colonel Bassot a fait, le 18 Octobre, une série complète d'observations du nadir, qui donnent *pratiquement* le même résultat que les miennes. Voici d'ailleurs les nombres définitifs pour toute la longitude.

β niveau − β nadir.

		s			s
Sept.	30	+0·124	Oct.	6	+0·236
	30	+0·121		18	+0·129†
Oct.	1	+0·199		18	+0·120†
	2	+0 216		26	+0·269
	3	+0·109		26	+0·248
	5	+0·125	Nov.	13	+0·157
	6	+0·183		13	+0·119

† "Par Bassot: et sans aucune correction aux nombres observés comme vous l'aviez suggéré d'abord."

"Réflexion faite et ayant consulté plusieurs astronomes, nous avons cru devoir prendre, comme vous dites, la moyenne des valeurs données par l'inclinaison et le nadir. Mais vous voyez que la correction appliquée aux niveaux ne peut donc être la cause de la différence que vous signalez entre les longitudes déduites des observations au transit-circle et des observations de Paris."

With respect to the note on October 18, I cannot find on referring to the original paper in which I drew up a list of these discordances any suggested alteration of the "nombres observés" on October 18, but there is a note that the results by striding level [β niveau] for that day were interpolated between those for October 17 and October 19, there being no direct observations on October 18. My data were obtained from the French computation books, the original note-books being in Paris; and no stellar observations having been made on October 18, the striding-level determinations were possibly omitted from these computations, but were recovered on referring to the original records. But I had clearly overlooked the fact that nadirs were taken by Colonel Bassot on this day, for I say in my former paper (p. 163): "It is to be remarked that the systematic correction to nadir observations was applied to the observations of B and D alike, although B did not make any nadir determinations. This may account for the discrepancy between their results." I was thus wrong in saying that B did not make any nadir determinations, but I am not clear that his observations do not rather support my view than condemn it. The mean value of the discordance found by D is $0^s{\cdot}176$, and by B (on one day only) is $0^s{\cdot}125$. The difference is $0^s{\cdot}051$, and its effect on the longitude $0^s{\cdot}051 \times \sec. 51° = 0^s{\cdot}08$, which reduces the discordance shown between B and D on p. 163 of my last paper from $0^s{\cdot}20$ to $0^s{\cdot}12$. And it is quite possible that the determination on October 18 would be more legitimately compared, not with D's whole series,

but with the determinations on October 6 and 26, in which case the suggested difference between B and D would be much larger, and would amply explain the whole discordance.

But the simplest way of regarding the matter is to reconstruct Tableau I. of the preceding paper for the two cases:

1. When the observations of the French instrument at Greenwich are reduced with level-errors obtained with the striding level.

2. When they are reduced with level errors given by nadir observations, taking only those nights when nadir observations were made. For the middle series in this case, we have only the single night October 18 on which no stellar observations were made; but I have supposed this nadir determination to apply to October 17 and October 19, as the best we can do.

TABLEAU I.

	Striding Level.				*Nadir.*			
	H T and L.	B and D.	H T and D.	B and L.	H T and L.	B and D.	H T and D.	B and L.
	s	s	s	s	s	s	s	s
Sept. 30	20·73	20·98	21·23	20·47	20·73	20·79	21·04	20·47
Oct. 1	20·77	21·02	21·25	20·56	20·77	20·71	20·94	20·56
3	20·98	21·12	21·32	20·72	20·98	20·95	21·15	20·72
5	20·97	21·04	21·27	20·73	20·97	20·84	21·07	20·73
Oct. 11	20·65	21·30	20·81	21·18	20·65	...	20·81	...
13	20·69	21·31	20·64	21·37	20·69	...	20·64	...
14	20·72	21·38	20·71	21·39	20·72	...	20·71	...
15	...	...	20·88	...	...	...	20·88	...
17	20·73	21·33	20·84	21·27	20·73	21·14	20·84	21·08
19	20·54	21·31	20·82	21·09	20·54	21·12	20·82	20·90
20	20·60	21·35	20·82	21·11	20·60	...	20·82	...
21	20·62	21·23	20·72	21·15	20·62	...	20·72	...
Oct. 23	21·30	21·10	21·45	20·96	21·30	...	...	20·96
26	21·07	20·97	21·20	20·72	21·07	20·56	20·79	20·72
27	21·19	...	...	...	21·19	...	...	...
30	21·12	21·08	21·36	20·89	21·12	...	...	20·89
Nov. 9	21·18	21·13	21·55	...	21·18	...	...	...
13	21·02	21·97	21·29	20·67	21·02	20·75	21·07	20·67
1st per.	20·86	21·04	21·27	20·62	20·86	20·83	21·05	20·62
2nd ,,	20·65	21·32	20·78	21·22	20·65	21·13	20·78	20·99
3rd ,,	21·15	21·05	21·37	20·81	21·15	20·66	20·93	20·81
1 and 2	20·76	21·18	21·02	20·92	20·76	20·98	20·92	20 81
2 and 3	20·90	21·19	21·08	21·02	20·90	20·90	20·86	20·90
Longde.	20·83	21·19	21·06	20·97	20·83	20·94	20·89	20·86

The results for longitude in the second case are thus moderately accordant, while those in the first are discordant. The accidental errors in the second case are of course larger, as the level-error depends on a single determination on each night instead of several.

The personal equations are as follow in the second case :—

H T − L	B − D	H T − D	B − L
s	s	s	s
−0·10	+0 15	−0·14	+0·19
−0·25	+0·24	−0·08	+0·09
−0·18	+0·19	−0·11	+0·14

in which there is nothing extravagantly discordant.

I do not insist that in view of the above systematic discrepancy between nadir and striding-level determinations one or other is clearly wrong; but it does seem to me that so large a systematic difference *suggests* some instrumental defect. The difference is larger than accidental differences should be. Did the observations stand alone, the only course would be to take the mean of the two series, as has been done in the French reductions. But the independent English operations seem to me to supply just the additional evidence required to enable us to choose between the two alternatives, instead of taking the mean.

(2) The differences of time-determination by the transit circle and by the longitude instruments are certainly somewhat irregular, but quite within the limits of what is possible, considering that different instruments and observers are compared. The parallelism of the four curves is not more pronounced than it should be, considering that one instrument (the transit circle) is compared with each of four others; and consequently its errors are common to the four curves. The obvious dip on October 26, for instance, is undoubtedly due to the transit-circle observations; and on careful scrutiny can be traced to a bad observation of *Polaris* by a young observer, from which the azimuth error on this day is deduced. It is to be remarked that the errors of the transit circle, though attributed to the observer A D, are really determined by many different observers, and reduced to A D by applying the assumed differences of personal equation.

(3) We now come to the real point at issue—the constancy of action of the relay. It is suggested that this time of action varied to the extent of some tenths of a second, according to the adjustment of the armature! If this were possible, it would make it almost impracticable to use relays in such work; but, fortunately, all the direct evidence available is against such an assumption.

In the first place, the indications of the sidereal standard through the relay on the longitude chronographs (E and F) were on many days directly compared with those without relay

on the Royal Observatory chronograph (R O) used in transit-circle observations. The following are the results :—

Date.	RO−E	RO−F
	s	s
Sept. 29	+0·04	+0·05
Oct. 17	+0·08	+0·08
19	+0·06	+0·05
20	+0·02	...
21	+0·03	...
23*	−0·02	...
27	+0·05	...
Nov. 13	+0·09	...

* On October 23 there is some evidence that one of the pens of chronograph E was loose.

These differences are not corrected for the "parallax of prickers" of R O. This quantity is about $0^s{\cdot}04$, but is neglected as constant in all transit-circle observations. Its sign is such as to diminish the above positive quantities, so that the time of action of the relay was always very small indeed. It is perhaps unfortunate that these comparisons were not made oftener, but it will be noticed that they were made in all three periods, and indicate no sensible difference in adjustment in the three periods, although the relay was adjusted by D or L in the first and third periods, and by B or H T in the middle period.

In the second place, if there were any fault in the relay, both French and English observations at Greenwich should be affected similarly. But nothing is clearer than that the fault, whatever it may be, affects the observations in opposite directions, or affects one and not the other. The difference between the time-determinations by B and H T, which was about $-0^s{\cdot}28$ at Paris during the first period, became $-0^s{\cdot}43$ at Greenwich during the second if the striding-level determination be accepted and returned to $-0^s{\cdot}32$ at Paris during the third. Similarly, the difference D − L was $-0^s{\cdot}30$ at Greenwich, became $+0^s{\cdot}08$ at Paris, and returned to $-0^s{\cdot}12$ at Greenwich.

If, then, we assume the Paris observations (against which nothing has been alleged by anybody) to be correct, the personal equations B−H T and D−L should be $-0^s{\cdot}30$ and $+0^s{\cdot}08$. But at Greenwich, if we accept the observations of striding level, these are found to be $-0^s{\cdot}43$ and $-0^s{\cdot}21$ respectively; and the action of the relay is here eliminated, for it was common to B and H T, and to D and L in the two cases. On the other hand, the nadir determinations, as far as they go, give $-0^s{\cdot}35$ and $+0^s{\cdot}14$.

For these two reasons, (a) that the time of action of the relay was, on all occasions on which it was tested, found to be

extremely small; (β) that its effect on time-determination was common to both observers at Greenwich, it does not seem to me that the discordance we are considering can be put down to the relay.

(4) The fourth paragraph in which I have summed up the paper of the French observers deals rather with matters of opinion. I have endeavoured in what precedes to keep mainly to facts. But, perhaps, I may say briefly that there does not seem to me to be any reason for rejecting the comparison with transit-circle observations, which was proposed by the Astronomer-Royal as an important item in the programme when the plan of the work was being discussed, and is a most valuable check on the results. Further, no clear reason has been given why the English result, $9^m\ 20^s{\cdot}86$, should not be near the truth (for the admitted variation in personality cannot seriously affect the longitude), and there is a very simple supposition, as has been pointed out in the earlier part of this paper, which would bring the French result into accordance with this.

Observations of Phenomena of Jupiter's Satellites at Windsor, New South Wales, in the Year 1890. By John Tebbutt.

Day of Obs.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of Nautical Almanac. h m s
July 14	I.	Tr. Ingr.	Ext. contact	8-inch	230	0 17 25	
14	I.	,,	Bisection	,,	,,	0 19 5	0 19
14	I.	,,	Int. contact	,,	,,	0 21 5	
14	I.	Occ. R.	First seen	,,	140	23 54 20	
14	I.	,,	Bisection	,,	,,	23 55 24	23 56
14	I.	,,	Last contact	,,	,,	23 56 59	
21	I.	Ecl. D.	Last seen	,,	130	23 9 55	23 9 57
22	I.	Tr. Egr.	Int. contact	,,	110	22 42 36	
22	I.	,,	Bisection	,,	,,	22 45 46	22 49
22	I.	,,	Ext. contact	,,	,,	22 48 6	
31	II.	Occ. D.	First contact	,,	130	21 46 22	21 49
31	II.	,,	Bisection	,,	,,	21 49 26	
Aug. 13	IV.	Tr. Egr.	Bisection	,,	110	20 17 52	20 26
13	IV.	,,	Ext. contact	,,	,,	20 21 41	
13	I.	Occ. D.	First contact	,,	170	22 54 50	
13	I.	,,	Bisection	,,	,,	22 58 15	22 58
13	I.	,,	Last seen	,,	,,	23 0 4	
14	I.	Tr. Ingr.	Ext. contact	,,	130	20 5 52	
14	I.	,,	Bisection	,,	,,	20 7 42	20 6
14	I.	,,	Int. contact	,,	,,	20 10 37	

Day of Obs.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of Nautical Almanac. h m s
Aug. 14	I.	Tr. Egr.	Int. contact	8-inch	130	22 22 29	
14	I.	„	Bisection	„	„	22 24 34	22 26
14	I.	„	Ext. contact	„	„	22 26 49	
15	I.	Ecl. R.	First seen	„	„	20 7 48	
15	I.	„	Full brightness	„	„	20 10 22	20 7 48
15	III.	„	First seen	„	„	20 46 47	20 47 41
16	II.	Tr. Ingr.	Ext. contact	„	„	21 15 9	
16	II.	„	Bisection	„	„	21 16 34	21 18
16	II.	„	Int. contact	„	„	21 18 44	
21	I.	„	Ext. contact	„	170	21 50 50	
21	I.	„	Bisection	„	„	21 52 54	21 51
21	I.	„	Int. contact	„	„	21 54 49	
21	IV.	Occ. D.	First contact	„	„	21 48 35	
21	IV.	„	Bisection	„	„	21 51 55	21 56
21	IV.	„	Last seen	„	„	21 55 24	
22	I.	Ecl. R.	First seen	„	„	22 2 50	
22	I.	„	Full brightness	„	„	22 5 1	22 2 51
23	III.	„	First seen	„	„	0 46 33	
23	III.	„	Full brightness	„	„	0 52 53	0 48 18

Day of Obs.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of Nautical Almanac. h m s
Aug. 25	II.	Ecl. R.	First seen	8-inch	170	21 50 53	21 51 28
25	II.	,,	Full brightness	,,	,,	21 53 6	
Sept. 7	I.	,,	First seen	,,	,,	20 22 6	20 22 1
7	I.	,,	Full brightness	,,	,,	20 24 22	
7	IV.	Ecl. D.	Last seen	,,	,,	21 24 42	21 28 37
8	II.	Occ. D.	First contact	,,	,,	22 19 17	
8	II.	,,	Bisection	,,	,,	22 21 22	22 20
8	II.	,,	Last seen	,,	,,	22 23 21	
14	I.	Ecl. R.	First seen	,,	,,	22 17 15	22 17 17
14	I.	,,	Full brightness	,,	,,	22 20 20	
15	IV.	Tr. Ingr.	Ext. contact	,,	,,	21 25 26	
15	IV.	,,	Bisection	,,	,,	21 30 25	21 49
15	IV.	,,	Int. contact	,,	,,	21 35 14	
16	III.	Tr. Egr.	Int. contact	,,	,,	22 27 42	
16	III.	,,	Bisection	,,	,,	22 30 22	22 35
16	III.	,,	Ext. contact	,,	,,	22 35 11	
22	I.	,,	Int. contact	,,	,,	20 9 35	
22	I.	,,	Bisection	,,	,,	20 12 54	20 15
22	I.	,,	Ext. contact	,,	,,	20 15 14	

Day of Obs.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of Nautical Almanac. h m s
Sept. 26	II.	Ecl. R.	First seen	8-inch	170	21 36 35	21 37
26	II.	,,	Full brightness	,,	,,	21 40 15	
27	III.	,,	First seen	,,	,,	20 51 28	20 53 56
27	III.	,,	Full brightness	,,	,,	20 55 45	
28	I.	Occ. D.	First contact	,,	,,	22 36 32	
28	I.	,,	Bisection	,,	,,	22 38 41	22 38
28	I.	,,	Last seen	,,	,,	22 40 6	
29	I.	Tr. Egr.	Bisection	,,	,,	22 3 34	22 6
29	I.	,,	Ext. contact	,,	,,	22 7 18	
Oct. 4	II.	Ecl. R.	First seen	,,	,,	0 14 3	0 14 23
4	II.	,,	Full brightness	,,	,,	0 17 11	
4	III.	Ecl. D.	Began to fade	,,	,,	21 15 44	21 22 48
4	III.	,,	Last seen	,,	,,	21 22 25	
5	III.	Ecl. R.	First seen	,,	,,	0 53 13	0 55 30
5	III.	,,	Full brightness	,,	,,	0 59 2	
7	I.	,,	First seen	,,	,,	22 32 11	22 32 6
7	I.	,,	Full brightness	,,	,,	22 34 50	
21	I.	Occ. D.	First contact	,,	,,	22 44 18	
21	I.	,,	Bisection	,,	,,	22 46 48	22 45
21	I.	,,	Last seen	,,	,,	22 48 7	

Day of Obs.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of Nautical Almanac. h m s
Oct. 22	I.	Tr. Egr.	Int. contact	8-inch	170	22 9 5	
22	I.	„	Bisection	„	„	22 11 59	22 14
22	I.	„	Ext. contact	„	„	22 14 4	
23	I.	Ecl. R.	First seen	„	130	20 51 45	20 51 43
23	I.	„	Full brightness	„	„	20 55 13	
26	II.	Tr. Ingr.	Ext. contact	„	170	21 40 9	
26	II.	„	Bisection	„	„	21 41 54	21 37
26	II.	„	Int. contact	„	„	21 44 23	
28	II.	Ecl. R.	First seen	„	140	21 26 19	21 26 14
28	II.	„	Full brightness	„	„	21 29 49	
30	I.	„	First seen	„	„	22 47 16	22 47 4
30	I.	„	Full brightness	„	„	22 49 29	
Nov. 5	III.	Tr. Ingr.	Ext. contact	4½-inch	180	22 2 45	
5	III.	„	Bisection	„	„	22 4 59	22 2
5	III.	„	Int. contact	„	„	22 8 29	
6	I.	Occ. D.	First contact	8-inch	170	21 5 58	
6	I.	„	Bisection	„	„	21 8 12	21 6
6	I.	„	Last seen	„	„	21 8 37	
13	IV.	Ecl. D.	Last seen	„	140	22 4 20	22 9 49

Remarks.

July 14.—Definition pretty good.

July 21.—Definition pretty good, but images rather tremulous. Satellite disappeared close to the planet's limb, and was very faint for a long time before final extinction. Observation not good.

July 22.—Definition fair and images pretty steady.

July 31.—Definition pretty good, but final disappearance not seen, in consequence of cloud.

August 13.—Definition not good at bisection of IV., but better at external contact; bisection observation certainly late. Bad definition in case of I.; the satellite distinguishable through the planet's edge till almost the time of final disappearance.

August 14.—Definition bad at ingress, and the observation of external contact too late; definition pretty good at egress.

August 15.—Images tremulous at reappearance of I., but more steady and the definition pretty good at that of III. Sky clear. Full brightness of I. unsatisfactory. III. came out nearly in contact with I., and its reappearance could not therefore be accurately observed.

August 16.—Images steady and fair definition.

August 21.—Definition excellent, and observations unusually good.

August 22.—Sky beautifully clear. Images steady, and definition pretty good. Moon present, and observation of first phase rather late.

August 23.—Sky still clear, and definition excellent. Satellite conspicuous at recorded time, and the observation therefore too late.

August 25.—Sky beautifully clear and definition fair, but Moon not far from planet.

September 7.—Sky beautifully clear, but images tremulous and badly defined. IV. disappeared and reappeared several times before final extinction at the recorded time.

September 8.—Good definition. Satellite visible through limb till near final disappearance.

September 14.—Sky clear. Images pretty steady, and definition fair. Satellite suspected 4·5 seconds earlier and distinct at recorded time.

September 15.—Definition fair at first two phases, but much disturbed at the last. Satellite remarkably faint before ingress, and 29 minutes after internal contact it was plainly seen as an elongated dark spot.

September 16.—Images steady and definition excellent.

September 22.—Sky clear and definition good.

September 26.—Sky clear near planet, and definition pretty good.

September 27.—Sky beautifully clear; images steady and definition pretty good. Observation of first phase probably a second late. Full Moon had risen.

September 28.—Definition pretty good, but final disappearance difficult to observe.

September 29.—Bad definition.

October 4.—Sky clear throughout, but images tremulous and badly defined for II., and definition pretty good for III.

October 5.—Sky still clear, but definition not quite so good. Satellite suspected 17·5 seconds earlier.

October 7.—Sky clear and definition pretty good.

October 21.—Bad definition.

October 22.—Bad definition.

October 23.—Sky beautifully clear, and definition pretty good. Satellite suspected three seconds earlier.

October 26.—Fair definition.

October 28.—Sky clear, and images well defined. Satellite suspected 1·5 second earlier.

October 30.—Sky clear, and images steady and well defined.

November 5, 6.—Images steady and well defined, but very difficult to observe the last phase of I.

November 13.—Sky very clear, but definition very bad. Satellite had already faded considerably at $22^h\ 0^m\ 55^s$. Satellite glimpsed at intervals till the recorded time, and was not afterwards seen.

Note.—An occulting bar was not employed in the eclipse observations. The times given in the first and seventh columns are the Windsor mean times of observation, diminished by $10^h\ 3^m\ 20^s.5$, and entered to the nearest second.

Windsor, N. S. Wales:
1891 *February* 11.

Ephemeris for Physical Observations of the Moon. By A. Marth.
1891 *May* 11 *to August* 31.

Greenwich Noon.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration. Sel. Long. of the Earth.	Geocentric Libration. Lat. of the Earth.	Combined Amount.	Direction.
1891.	°	°	°	°	°	°
May 11	305·34	−0·43	+5·65	−2·97	6·37	242·2
12	317·57	0·41	5·30	4·26	6·79	231·1
13	329·80	0·38	4·64	5·31	7·04	221·0
14	342·02	0·36	3·73	6·09	7·13	211·3
15	354·24	0·33	·63	6·59	7·09	201·6
16	6·45	0·30	1·41	6·80	6·94	191·7
17	18·66	−0·28	+0·15	−6·72	6·72	181·3
18	30·87	0·25	−1·08	6·34	6·44	170·3
19	43·07	0·22	2·23	5·69	6·11	158·6
20	55·26	0·19	3·24	4·78	5·77	145 9
21	67·45	0·16	4·06	3·63	5·44	131·8
22	79·64	0·13	4·66	2·28	5·19	116·1
23	91·82	0·10	5·02	−0·79	5·08	98·9
24	104·00	−0·07	−5·12	+0·77	5·18	81·4
25	116·19	0·04	4·97	2·32	5·48	64·9
26	128·38	−0·01	4·57	3·77	5·92	50·4
27	140·58	+0·02	3·96	5·01	6·40	38·2
28	152·78	0·05	3·15	5·98	6·76	27·7
29	164·98	0·08	2·20	6·60	6·95	18·4
30	177·29	0·11	1·15	6·81	6·90	9·5
31	189·41	+0·14	−0·04	+6·62	6·62	0·4
June 1	201·64	0·16	+1·06	6·01	6·11	350·0
2	213·88	+0·19	+2·12	+5·04	5·47	337·2
June 10	311·86	+0·37	+3·63	−5·86	6·89	211·7
11	324·10	0·40	2·72	6·45	6·99	202·7
12	336·33	0·42	1·63	6·75	6·95	193·5

Greenwich Noon.	Selenographical Colong. of the Sun.	Lat. of the Sun.	Geocentric Libration. Sel. Long. of the Earth.	Lat. of the Earth.	Combined Amount.	Direction.
1891.	°	°	°	°	°	°
June 13	348·56	+0·45	+0·43	−6·76	6·77	183·6
14	0·79	+0·47	−0·83	−6·47	6·52	172·7
15	13·01	0·50	2·08	5·90	6·25	160·7
16	25·23	0·53	3·23	5·07	6·01	147·6
17	37·43	0·56	4·22	4·01	5·81	133·6
18	49·63	0·58	4·97	2·73	5·67	118·8
19	61·83	0·61	5·44	−1·29	5·59	103·4
20	74·02	0·64	5·57	+0·25	5·58	87·4
21	86·22	+0·67	−5·36	+1·82	5·66	71·2
22	98·41	0·70	4·81	3·32	5·84	55·3
23	110·60	0·73	3·96	4·65	6·10	40·3
24	122·79	0·75	2·86	5·71	6·39	26·5
25	134·99	0·78	1·62	6·42	6·62	14·1
26	147·19	0·80	−0·31	6·73	6·74	2·6
27	159·40	0·82	+0·95	6·62	6·68	351·8
28	171·62	+0·84	+2·11	+6·09	6·44	341·0
29	183·84	0·86	3·10	5·19	6·05	329·3
30	196·07	0·88	3·89	4·00	5·58	315·9
July 1	208·31	0·90	4·47	2·59	5·17	300·1
2	220·55	+0·92	+4·84	+1·05	4·96	282·3
July 10	318·55	+1·07	+0·78	−6·67	6·71	186·7
11	330·79	1·09	−0·45	6·45	6·47	176·0
12	343·02	+1·11	−1·74	−5·96	6·21	163·7
13	355·25	1·13	3·02	5·21	6·02	149·9
14	7·47	1·15	4·22	4·23	5·97	135·2
15	19·69	1·17	5·24	3·04	6·06	120·2
16	31·90	1·19	6·01	1·69	6·24	105·7
17	44·11	1·21	6·44	−0·21	6·45	91·9
18	56·31	1·23	6·48	+1·31	6·61	78·5
19	68·50	+1·24	−6·08	+2·81	6·70	65·1
20	80·69	1·26	5·25	4·19	6·71	51·3
21	92·88	1·28	4·02	5·34	6·67	36·9
22	105·07	1·30	2·48	6·16	6·63	21·9
23	117·26	1·31	−0·78	6·57	6·62	6·7
24	129·45	1·33	+0·94	6·55	6·61	351·9
25	141·65	1·34	2·53	6·09	6·59	337·5
26	153·86	+1·35	+3·88	+5·24	6·52	323·6
27	166·07	1·36	4·93	4·08	6·39	309·7

Greenwich Noon.	Selenographical Colong. of the Sun.	Lat.	Geocentric Libration. Sel. Long. of the Earth.	Lat.	Combined Amount.	Direction.
1891.	°	°	°	°	°	°
July 28	178·29	+1·37	5·64	+2·71	6·25	295·7
29	190·51	1·38	6·03	+1·21	6·15	281·3
30	202·74	1·39	6·13	−0·33	6·14	266·9
31	214·97	1·40	5·98	1·82	6·25	253·1
Aug. 1	227·21	+1·41	+5·64	−3·18	6·48	240·5
Aug. 9	325·17	+1·47	−2·34	−5·23	5·73	155·9
10	337·40	1·48	3·66	4·30	5·65	139·6
11	349·62	1·49	4·90	3·17	5·84	123·0
12	1·84	1·50	5·98	1·89	6·27	107·6
13	14·06	1·51	6·81	−0·49	6·82	94·1
14	26·26	1·51	7·29	+0·97	7·36	82·4
15	38·46	1·52	7·36	2·43	7·75	71·7
16	50·66	+1·53	−6·93	+3·80	7·90	61·2
17	62·85	1·53	6·00	4·99	7·80	50·1
18	75·03	1·54	4·59	5·90	7·47	37·8
19	87·21	1·54	2·80	6·43	7·01	23·5
20	99·39	1·54	−0·78	6·52	6·56	6·8
21	111·57	1·54	+1·28	6·15	6·28	348·3
22	123·75	1·54	3·20	5·36	6·24	329·2
23	135·94	+1·54	+4·82	+4·22	6·40	311·2
24	148·13	1·54	6·05	2·83	6·68	295·1
25	160·33	1·54	6·85	+1·31	6·98	280·8
26	172·54	1·53	7·24	−0·25	7·24	268·0
27	184·75	1·53	7·25	1·75	7·46	256·4
28	196·97	1·53	6·95	3·12	7·62	245·7
29	209·19	1·52	6·40	4·31	7·71	235·9
30	221·42	1·52	5·65	5·27	7·72	226·9
31	233·65	+1·51	+4·75	−5·97	7·62	218·3

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LI. MAY 8, 1891. No. 7

Lieut.-General J. F. TENNANT, R.E., C.I.E., F.R.S., President, in the Chair.

Alfred Henry Fison, D.Sc., University College, London, W.C.;

Thomas Gordon, F.R. Met. Soc., 9 Scotch Street, Whitehaven;

George E. Hale, B.Sc., 4545, Drexel Boulevard, Chicago, U.S.A.;

were ballotted for and duly elected Fellows of the Society.

The following candidate was proposed for election as a Fellow of the Society, the name of the proposer from personal knowledge being appended:—

Oliver Joseph Lodge, D.Sc., LL.D., F.R.S., Professor of Physics, University College, Liverpool (proposed by G. H. Darwin).

Seventy-seven presents were announced as having been received since the last meeting, including amongst others:—

E. Dunkin, The Midnight Sky: new edition, presented by the author; Leander McCormick Observatory publications, vol. i. part 5 (Durchmusterung $-23°$), presented by the Observatory; Harvard College Observatory, Annals, vols. xxiii. part 1, and xxvii. (Observations with the Meridian Photometer, 1882–88, and The Draper Catalogue of Stellar Spectra), presented by the Observatory; C. A. Young, Lessons in Astronomy, including Uranometry, presented by E. Arnold; 'Munich Obser-

vatory, Neue Annalen, Band i., Erstes Münchener Sternverzeichniss von 33082 Sternen, presented by the Observatory; Pulkowa Observatory, Catalog von 5634 Sternen aus den Beobachtungen 1874–80, presented by the Observatory; Photograph of cluster in *Perseus*, made at the Lick Observatory, presented by E. S. Holden.

Further Experience regarding the Magnitude of Stars as obtained by Photography in the Oxford University Observatory. By the Rev. Professor C. Pritchard, D.D., F.R.S.

Notwithstanding all that passed at the recent meeting of the Paris Congress, doubt seems still to exist as to the photographic representation of the photometric magnitudes of the fainter stars, and of the time required for the impression of these faint stars on a photographic film. For instance, the experience of the Oxford Observatory, founded on the examination and discussion of some thirty-six plates, proves that the time necessary for photographing a star of the 11th magnitude, in a condition admitting of bisection and measurement, is on the very finest nights 200 seconds; whereas the experience of Greenwich, founded, it is believed, on the examination of a smaller number of plates, is that, under the same favourable atmospheric conditions, a star of the 11th magnitude may be photographed and subsequently measured after an exposure of only 96 seconds. Under less favourable meteorological conditions, it has been found necessary at Oxford, in order to photograph stars of the 11th magnitude, to prolong the exposure to 5 and even 8 minutes, while at Greenwich an exposure of 4 minutes is the longest contemplated.

I have considered it desirable to examine this question in still greater detail than in the paper which I communicated to the Paris Congress, and I may say that the general result has been to completely confirm the conclusions which I had previously obtained. The methods which I adopted have been twofold. In the first place, I photographed a district, delineated in the charts of the late Professor Peters, with exposures of 3, 4, 6, 8, and 15 minutes. These charts were chosen because they give the configurations of a considerable number of reputed 11th magnitude stars, and therefore permitted an easy comparison. The result of the examination of the plates was as follows:

After 3 min. exposure, 31 per cent. of Peters' stars were photographed.

4	,	42	„	„	„
6	„	62	„	„	„
8	,	78	„	„	„

But some stars were not visible after 15 minutes' exposure. A photometric determination of the brilliancy of some of the fainter stars with the wedge photometer proved, that

After 4 min. exposure, stars of 10·5 mag. were measurable.
6 „ „ 11·0 or 11·2 „
8 „ „ 11·5 or 11·7 „

This proved that many stars on Professor Peters' charts were fainter than the 11th magnitude, though no symbol indicating a fainter magnitude is used in the construction of the chart.

For this reason, and also because the charts do not extend to an altitude at which the Oxford zone will have to be photographed, it was determined to take an additional trial-plate in the actual zone, and photometrically to measure the magnitude of stars of approximately the 11th magnitude. The night chosen was exceptionally fine and the definition much above the average. An examination of the plate proved that 11th magnitude stars were measurable after 4 minutes' exposure, and possibly after 3 minutes' exposure. It was considered that $3\frac{1}{2}$ minutes or 210 seconds would on that night have been sufficient to effectually record the places of stars of the 11th magnitude.

These discrepancies, if discrepancies they can properly be called, between the results here given and those recorded by the Astronomer Royal may to some extent be explained by the superiority of the Greenwich instrument over that in use at Oxford. The images produced by the Greenwich object-glass are exceptionally small and condensed, and are said to be readily discernible when having a diameter of $2''{\cdot}5$, whereas on the Oxford plates the diameters of the smallest images sufficiently distinct for measurement vary from $3''{\cdot}2$ to $3''{\cdot}5$. The great accuracy of the driving mechanism of the Greenwich Equatoreal, rendering for the most part the uncertain and often exaggerated action of the manual control unnecessary, is doubtless an assistance in producing the small black images characteristic of the Greenwich plates, as exhibited at the Paris Congress. Reference is here made to this fact solely with the view of accounting for the discrepancies which unquestionably exist in the time recorded as necessary for the impression of images of a specified magnitude, such as the 11th. Fortunately, the Congress have recognised the difficulty, and arrived at a practical solution, by recommending each Observatory to determine in its own particular case the time necessary to impress stars of the 11th magnitude on the sensitised film.

The plan proposed by the Congress is that in each Observatory a star of the 11th magnitude shall be artificially formed by reducing a star of the ninth two units of brightness, by means of a metallic gauze of a definite mesh, supplied to each Observatory, and placed in front of the object-glass. Moreover, a small catalogue is to be furnished to each Observatory of stars

definitely accepted as of the ninth magnitude. As I have myself been placed by the Congress on a committee for the execution of this scheme, I shall, if it be thought desirable by my colleagues, be perfectly ready to furnish the catalogue, and also to examine the gauze necessary for the purpose described. At the same time, I think it will greatly facilitate the object in view, if I were to supplement the necessary list of stars of the 9th magnitude by another catalogue of the 11th magnitude photometrically determined, selected from the same typical areas as those in which the stars of the 9th magnitude will be found. For general convenience this catalogue of stars will be selected from a zone about 8° north of the Equator. The magnitudes of all these stars will be determined at Oxford by the application of the wedge photometer, keeping strictly in view the average scale found in Argelander's work.

The foregoing remarks apply solely to the stars which are intended to form the International Catalogue of all stars to the 11th magnitude, but the Congress have decided that there is to be a chart formed containing stars of a much inferior brightness. It was originally presumed that this order of faintness was to extend to magnitude 14, as defined by the 1887 Congress. Experience, however, has shown that stars of the photometric magnitude 14 require a time of exposure which would render so extensive a chart practically unattainable, and this amount and uncertainty of the time required seems to have led the Congress to the practical issue conveyed by the following minute:—

'Le comité permanent indique quarante minutes comme la durée de la pose pour les clichés de la carte, dans les conditions atmosphériques moyennes à Paris, et avec les plaques Lumière actuellement en usage à Paris.'

As a matter of fact, I believe that no star of magnitude 14 has hitherto been photometrically determined; at all events, I have never been able myself to measure a star of this degree of faintness. The wedges employed for stars, recorded in the *Uranometria Nova Oxoniensis*, when applied to the Oxford 12¼-inch object-glass, extinguish stars between the 9th and 10th magnitude, and are inapplicable to fainter objects. Under these circumstances, I requested Mr. Hilger to furnish me with a wedge capable of determining the magnitude of stars of inferior brightness; and he, not without great difficulty, has constructed for me a wedge applicable to stars a little fainter than magnitude 12. If such a wedge could be applied to an object-glass of twice the aperture of that of the Oxford equatoreal, it would be available for the extinction of stars of the approximate magnitude of 13·5, and if such a wedge were applied to an object-glass three times the aperture—that is, to about the size of the Lick refractor—it might possibly be applicable to the photometric determination of stars about magnitude 14·5. Such

then, is the state of the case in reference to existing photometric apparatus, exhibiting the extreme difficulty of the accurate determination of magnitudes so faint. The word "approximately" is here used because it is by no means probable that the light admitted by a thick and compound object-glass is accurately proportioned to the area of glass exposed.

Yet, and notwithstanding these statements, it is quite certain that astronomers, including myself, have repeatedly photographed in the Pleiades stars unquestionably fainter than magnitude 14. In one plate of the Pleiades, taken at Oxford, with a three hours' exposure, I have no manner of doubt but that more than one hundred stars fainter than the 14th are there visibly impressed, and it is equally certain that stars of the 14th magnitude have even been copied therefrom. Still, absolutely accurate measurements of these faint stars are, by me, at least, unattainable. The question, therefore, immediately arises, How can we speak definitely of the order of brightness of these faint Pleiades stars?

In the year 1887, in a paper printed in the Proceedings of the Royal Society, I believe I, for the first time, obtained a mathematical expression connecting photometric brightness with photographic diameter. The formula therein given is the equivalent of the now well-known expression:—

$$M = a - b \log. D.$$

Supposing, then, that proper measurements and this formula are applied to stars on the Pleiades plate already referred to or any other suitable plate, it is possible to determine the constants a and b for that plate, so as to furnish a curve reaching from magnitude 4 to magnitude 12, the stars employed being all photometrically determined. In the actual case quoted, the formula is

$$M = 19{\cdot}23 - 9{\cdot}67 \log. D.$$

That represents all stars to magnitude 12, and theoretically is applicable to stars of a fainter magnitude; but the expediency of thus pushing the formula beyond a magnitude, unascertained by a photometric process, is not established.

To test the applicability of the formula to the determination of the magnitude of stars fainter than those employed in deducing it, I have taken the measured diameters of stars not fainter than the 9th magnitude, and from the expression thus deduced I have computed the diameters of stars of the 11th magnitude which could be directly compared with the measured quantities. I have also, with a curve founded on measures of stars brighter than the 10th magnitude, deduced the diameters of stars of the twelfth order of brightness. In each case I have found a very close agreement with the diameters read from the curve, the deviation not being greater than is the uncertainty of the interpolating curve itself. From these facts I conclude that

it is safe to trust the deductions from the equation for at least two magnitudes beyond those employed in deducing it, and that consequently an adequate appreciation of stars of the 14th magnitude is possible.

But when it was originally proposed as a part of the international project to attain a photographic chart of the heavens, including stars of the 14th magnitude, it must not for a moment be overlooked that this magnitude 14 (limited by the definition attached to it by the Congress) did not necessarily mean magnitude 14 photometrically determined.

The definition of photographic magnitude made in 1887 implied that an increase in the intensity of the source of light was exactly equivalent to increasing the time of exposure in the same proportion. I am not disposed to admit or to controvert the general proposition. It certainly wears a general aspect of probability, but if the result of exposure of a plate to stars be measured by the diameters of the discs impressed, which seems to me the only adequate and practical method of measuring the photographic action, I then doubt the proposition altogether. The actinic action must be regarded in its entirety, and surely extends not to the area of the blackened disc alone, but to its depth and its mass. The visibility of the stars on the film, however, depends entirely on the diameter of the disc, though in very feeble stars the colour of the disc is no doubt of importance.

In order to ascertain practically the connection between magnitude and time of exposure, a series of Pleiades plates were taken with exposures of 20^s, 50^s, $2^m\ 5^s$, and so on up to 32^m, each of these exposures being $2\frac{1}{2}$ times that of the preceding, and consequently representing the steps of the conventional consecutive magnitudes. The diameters of the discs of the same star with these various successive exposures were then measured, wherein it is evident, if the diameter be assumed as the measure of actinic action, that the diameter of a star of the 3rd magnitude with the shortest exposure will be the same as that of the 4th magnitude exposed for 2·5 times as long, and the same rule will obtain with feebler magnitudes exposed for a proportionate longer time, it being well understood that the trials extend over a considerable number of stars, but for obvious reasons situated as near the centre of the plate as possible. The invariable result is that the fainter stars require a much longer exposure than that implied by the corresponding powers of 2·5, in order to obtain equality of diameter with the brighter stars. For example, a star of the 5th magnitude with an exposure of 50^s has a diameter of 9 div., but a star of the 9th magnitude exposed for $(2{\cdot}5)^4 \times 50^s$ has a diameter of only 7 div. The following table exhibits the average results of many measurements of the diameters of star-images. The first two columns give respectively the mean photographic and photometric magnitudes of the stars as determined either from the measured diameter of the

star disc or the wedge photometer. It may be added that the star magnitudes in either column accord very well with those given by other authorities. The remaining columns give the diameters of the measured discs expressed in parts of the scale.

Table showing the mean diameters of groups of stars, given with exposures varying by successive powers of 2·5.

Mean Photographic Magnitude.	Mean Photometric Magnitude.	Diameter, after an exposure of					
		s 20 div.	s 50 div.	m s 2 5 div.	m s 5 12 div.	m 13 div.	m s 32 30 div.
3·46	3·2	9·6	...	...	...	...	...
4·39	4·2	8·2	9·5	...	...	...	...
5·47	5·4	6·25	7·85	9·15	...	...	...
6·51	6·5	4·37	5·90	7·20	8·62	...	...
7·43	7·4	...	3·80	4·90	6·27	7·93	...
8·52	8·4	...	...	3·45	4·45	5·65	7·05
9·46	9·5	...	...	...	3·30	4·4	5·60

The inspection of this representative table is a sufficient indication that the time required for the impression of a star of the 9th magnitude, for example, required to have a definite diameter is by no means sufficiently determined by the continued multiplication of the time required by a brighter star by the appropriate power of 2·5.

It will be seen from this that when the International Committee determined to construct a chart of stars with an exposure of forty minutes, or thereabouts, which time was determined on a certain hypothesis, it must not be expected that the 14th magnitude, as ordinarily or photometrically conceived, will necessarily appear on the plates. As to what order of faintness will be impressed on the average will not be known for a long time to come.

Before concluding this paper it may be as well to state that these numerous measurements of diameter have been completed at Oxford solely by the device of the wedge-lines ruled on a glass plate, described in *Monthly Notices*, vol. li., p. 223. On one plate alone some 800 stars were measured, and the magnitudes determined in about nine hours.

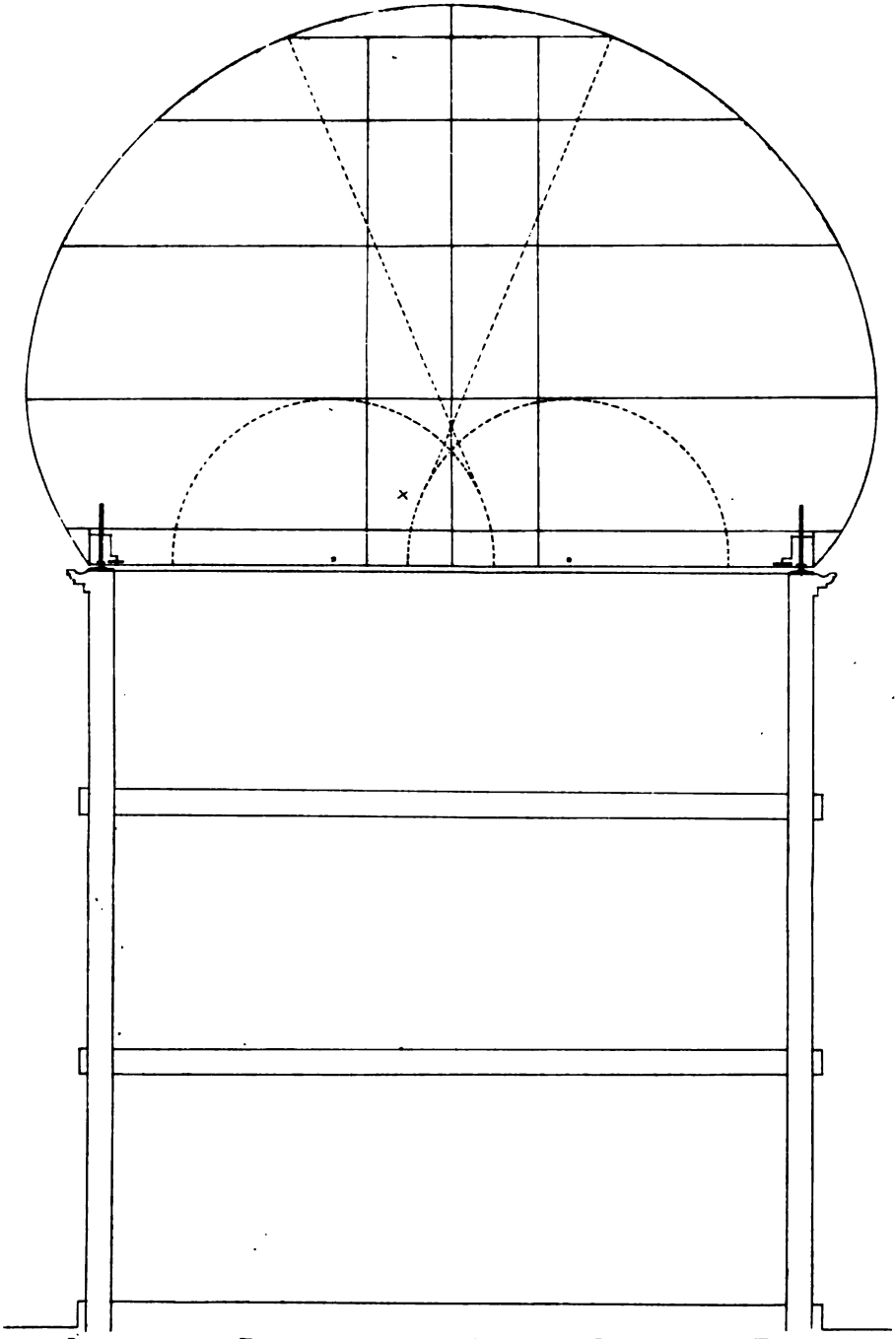
On a New Dome to be erected at the Royal Observatory, Greenwich.
By W. H. M. Christie, M.A., F.R.S., Astronomer Royal.

In the last Report of the Council (*Monthly Notices*, vol. li., p. 209) mention was made of a proposal to replace the existing wooden south-east dome (of cylindrical form) by an iron-framed dome of larger diameter, better suited to the new 28-inch refractor, which is now nearly ready. This proposal has received the sanction of the Admiralty, and the new dome is now being constructed by Messrs. T. Cooke and Sons, of York. As the conditions which it has to satisfy are peculiar, and as the plan proposed presents some novel features, it may be of interest to give a general description of it.

In order to accommodate the new 28-inch refractor of 28 feet focal length, a dome of 36 feet diameter is desirable; but as the external diameter of the circular wall-plate on which the dome runs is only 31 feet 4 inches, a peculiar form of dome is necessary. The form adopted is the surface generated by the revolution of an involute of a circle, 7 feet in diameter, with its centre in the plane of the rail, and 5 feet from the axis, the curve being completed near the apex by an arc of a circle (of 13 feet 3 inches radius) so that it cuts the axis at right angles. The diameter of the dome is 36 feet at a height of 7 feet above the rail, contracting to 31 feet at the plane of the rail. The varying curvature of the involute appears to be well adapted to the conditions, the contraction in the lower part of the dome to the diameter of 31 feet being rapid, owing to the sharp curvature, while the increasing curvature towards the apex gives ample height, and improves the appearance of the dome.

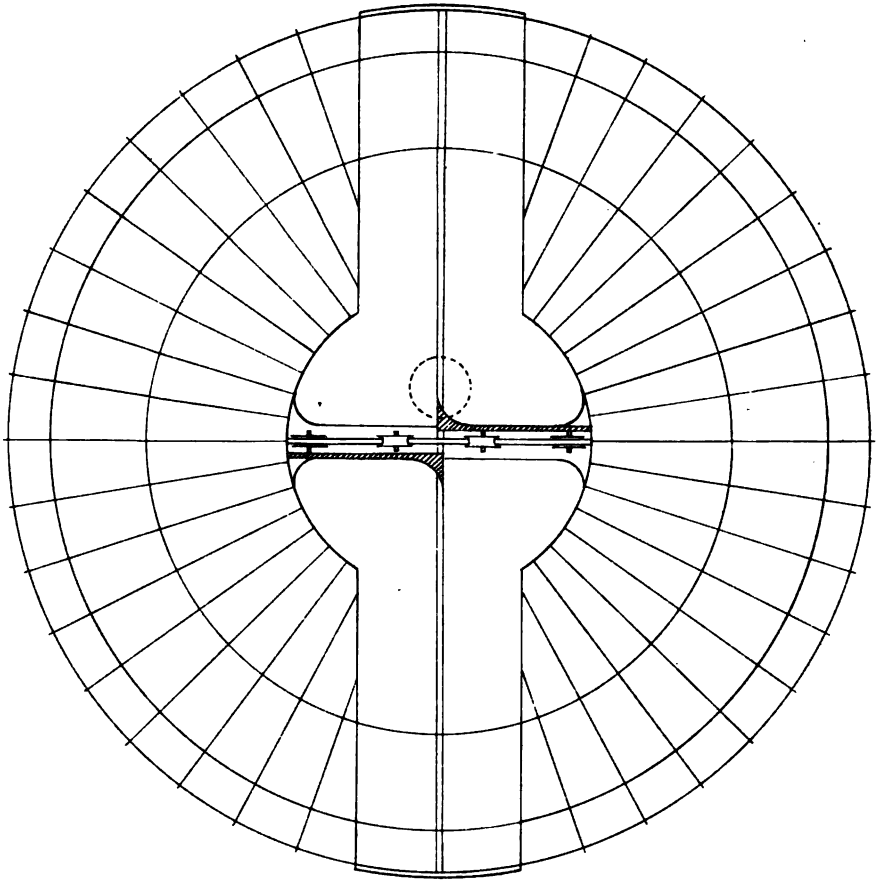
The framework of the dome is to be generally similar to that of the Lassell dome (constructed by Messrs. T. Cooke and Sons), consisting of T-iron vertical curved ribs, tied together by horizontal circular ribs (of T or angle iron) cut through at the shutter-opening on both sides of the zenith, the opening being framed with vertical girders connected by a strong broad-flanged rib at the apex of the dome. As the centre of the instrument is two feet south of the axis of the dome and tower, this connecting-rib would not interfere with the view of the zenith. The base of the framework will be a stiff circular girder, 18 inches deep, the section of the girder being a right-angled triangle, the hypothenuse of which is formed by the ribs and papier-mâché covering of the dome. Thus the dome virtually consists of two semi-domes, resting on the continuous circular girder, and tied together at the zenith. It is proposed to use some form of papier-mâché as the covering of the dome, the vertical T-ribs being outside the covering, with the flat face towards the paper, and the horizontal circular ribs inside, also with the flat face towards the paper.

Fig. 1.



SECTIONAL ELEVATION OF NEW S.E. DOME AND TOWER,
ROYAL OBSERVATORY GREENWICH.

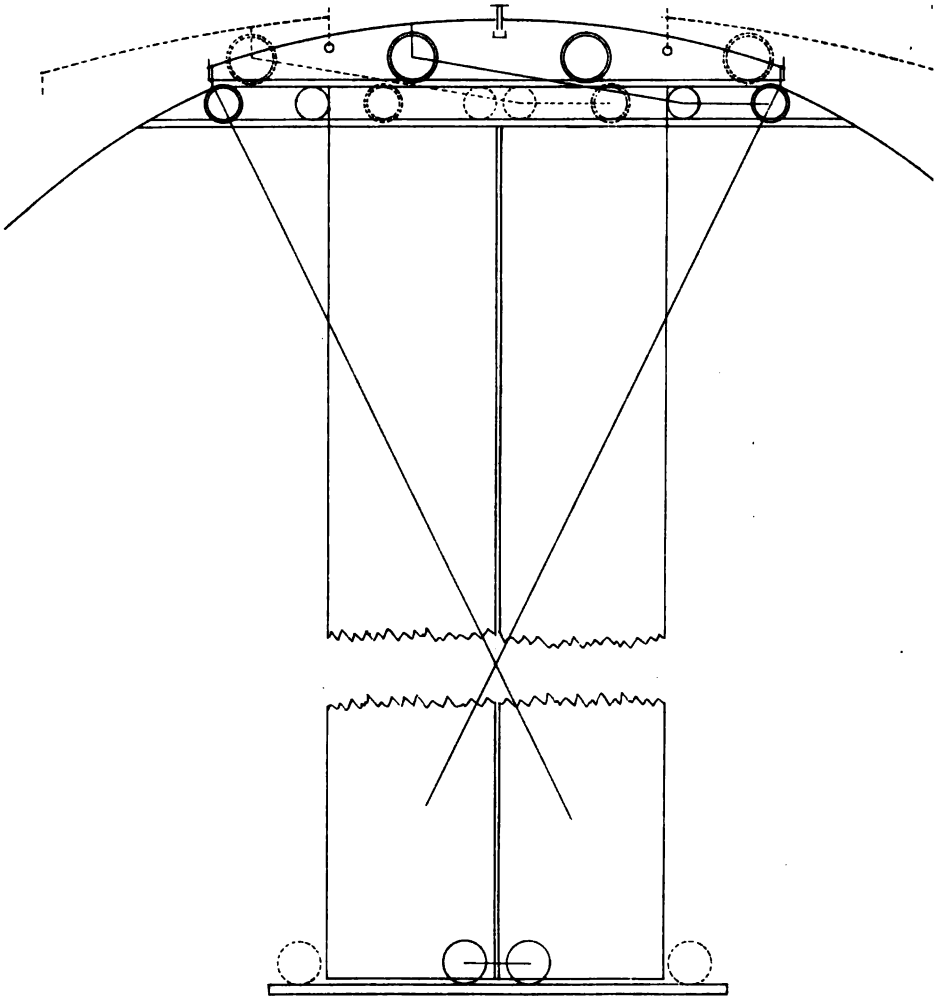
Fig. 2.



PLAN OF DOME

Scale ⅛ inch to a foot. (nearly)

Fig. 3.



SECTIONAL ELEVATION OF SHUTTER.

Scale ¼ inch to a foot.

Spottiswoode & Co. Lith. London

The revolving arrangements will be similar to those introduced by me in the Lassell dome, viz. a system of vertical rollers, about two feet in diameter, attached to the circular girder of the dome, and running freely on a planed horizontal rail, the bearing-surface of the rollers being slightly rounded, so as to avoid any drag. Excessive lateral motion from the force of the wind, or other cause, is prevented by horizontal rollers carried on the same bracket as the vertical rollers, and so adjusted as only to come into bearing occasionally against the vertical face of the rail, when required to keep the vertical rollers from running off the rail. This system has been found to work very satisfactorily in the case of the Lassell dome, which runs very lightly after seven years' use.

The arrangement of the shutter is another matter which has required careful consideration. In the plan adopted I have aimed at securing the conditions:—(1) that there should be a wide opening, (2) that the shutter should open easily, (3) that it should present a symmetrical appearance externally, and (4) that the opening should be of the same width throughout on both sides of the zenith, so as to allow the air to pass freely through in the neighbourhood of the object-glass. The shutter, as arranged, is in two parts, with a division right down the middle, each half being a balanced shutter, 3 feet 6 inches wide, which extends right over the dome from the curb, through the zenith to the opposite part of the curb, and traverses to one side on a narrow rail (about 13 feet long) at the zenith, and on two broad rails attached to the opposite part of the curb at the bottom of the shutter on each side of the zenith. Each half of the shutter runs on a double-flanged bearing-wheel (say 1 foot in diameter), which it carries nearly vertically over its centre of gravity (so that it nearly balances on it, leaving a small excess of weight on the outer side), and it also carries a smaller double-flanged guiding-wheel on a stiff tail-piece, extending across the shutter opening to the other end of the rail. The flanged bearing-wheel runs on the upper side of the rail, and the guiding-wheel on the under side, so that it does not interfere with the bearing-wheel of the other half of the shutter. The tail-pieces (about $7\frac{1}{4}$ feet long) are bolted to the edges of their respective shutters on either side of the zenith, so that they run clear of each other when the shutters are opened. To guard against the possibility of the shutter being lifted by the wind, the tail-pieces may carry a supplementary roller (between the bearing and guiding rollers) running clear below the rail and just above a guard-rail fixed below it. The rail and the bearing and guiding wheels are under the shutter and covered by it when closed. Near the zenith the parallel curved girders of the shutter-opening, and the parallel outside edges of the shutters, are replaced by arcs of an horizontal circle (say 13 feet in diameter), allowing space under this part of the shutter for the rail (13 feet long), wheels, and guiding-pieces. Thus an opening,

7 feet clear throughout on both sides of the zenith, can be obtained when the shutters are opened to their fullest extent. The arrangement adopted for the tail-pieces in combination with the circular form of the shutter near the zenith, allows of a greater length in the guide for traversing the shutter. The weight of the shutter is carried chiefly by the bearing-wheel at the zenith, and in a small degree by wheels (without flanges) at the bottom of the shutter on each side of the zenith, which run on rails without lateral constraint, and serve to maintain the balance. Horizontal rollers (with flanges underneath) mounted on the same brackets would also serve for this purpose, and as wind-guards to prevent the shutter being lifted by the wind. The shutters may be opened and shut by means of tackles attached near the zenith.

The figures show the general arrangement of the dome. Fig. 1 is a sectional elevation of the dome and tower, showing the divided shutter, the circular girder with vertical and horizontal rollers, and the horizontal circular ribs. The two semicircles (dotted) are the generating circles of the involute. The position of the centre of the equatoreal is indicated by a cross. Fig. 2 is a plan of the dome, above the equator, showing the vertical and horizontal ribs, the broad-flanged connecting-rib, and the shutters with the tail-pieces, rollers, and rail. The dotted circle represents the 28-inch object-glass pointing to the zenith. Fig. 3 is a vertical section showing the shutters with the tail-pieces, rollers, and rails, at the zenith and at the bottom. The dotted lines indicate the position when the shutters are open. The three rollers connected by lines are attached firmly to the left-hand shutter, the upper left-hand and lower right-hand rollers being double-flanged wheels which run on the upper and under sides of the upper rail respectively, and the intermediate (lower) roller being a guard-wheel between the upper and lower rails to prevent the other two wheels being thrown off the rail by the action of the wind. The rollers at the bottom are without flanges, and are carried by brackets, so that when the shutters are opened they pass clear behind the vertical girders of the opening, and run on a rail fixed on the circular girder entirely within the dome.

Royal Observatory, Greenwich:
1891 *May* 7.

Photographs of Neptune and its Satellite. By Isaac Roberts, F.R.S.

Sixteen photographs of the planet *Neptune* were taken at my observatory between December 9, 1890, and February 24, 1891, with exposures of the plates varying between fifteen minutes and three hours respectively. Upon eight of the plates the satellite is to be seen, and I have prepared the accompanying diagram to show its positions by measurements of the eight plates. The diameter of the photographic image of *Neptune* in my telescope is about equal to the major axis of the projected orbit of the satellite. The satellite can, therefore, be photographed only when it is somewhere within the distance of about 45° of the line of apsides, and if the planet did not mask the satellite in the other parts of its orbit the orbital motion would be too rapid to permit a photographic image being formed.

The large circle, fig. 1, represents the photographic image of *Neptune*, and the eight small circles around it those of the satellite. It is difficult to measure with accuracy the position angles of the satellite, because its image is generally very faint and undefined in outline by reason of the orbital motion; and the relatively large image of the planet adds to the difficulty in finding the line joining their centres. The position angles given in the following table are the nearest approximations practicable under these conditions.

Approximate position angles of the satellite :—

	°	′
No. 1, 1890, December 9, exposure 3 hours; sidereal time, 5h. 25m....	59	28
No. 2, 1890, December 12, exposure 15 minutes; sidereal time, 4h. 59m.	232	40
No. 3, 1891, January 10, exposure 60 minutes; sidereal time, 4h. 14m.	261	46
No. 4, 1891, February 1, exposure 84 minutes; sidereal time, 5h. 31m.	31	29
No. 5, 1891, February 4, exposure 50 minutes; sidereal time, 5h. 4m.	207	6
No. 6, 1891, February 10, exposure 75 minutes; sidereal time, 6h. 5m.	193	55
No. 7, 1891, February 20, exposure 90 minutes; sidereal time, 6h. 54m.	277	3
No. 8, 1891, February 24, exposure 75 minutes; sidereal time, 6h. 45m.	44	53

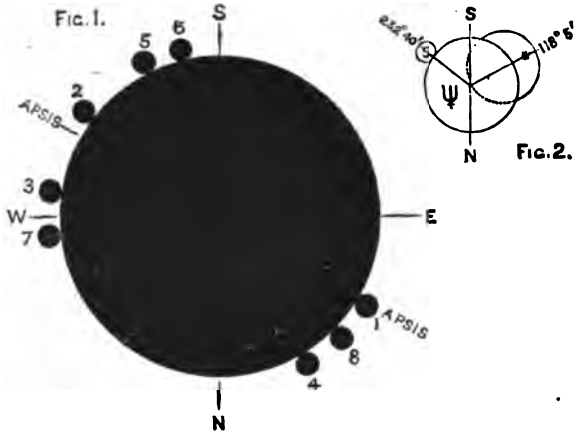
The sidereal time given in the above table is that at the middle of each exposure for the meridian of Crowborough, 37^s East of Greenwich.

On December 12, 1890, *Neptune* was in conjunction with the star D.M., +19°, 699, R.A. $4^h\ 11^m\ 17^s{\cdot}5$, dec. +19° 24′·6, mag. 9.4, and the relative positions of the star, planet, and satellite are shown on the diagram, fig. 2. At sidereal time $4^h\ 59^m$ the position angle of the planet and star was 118° 5′, and that of the satellite 232° 40′. The distance of the planet and star, measured from centre to centre, was 10″·85 of arc. The

measured photo-diameter of the planet was 12″·21, and of the star 9″·5.

In the event of any computations being made touching the subject of this communication, the sixteen negatives referred to will be available for measuring positions and distances between the planet and the surrounding stars during the opposition of *Neptune* in 1891.

The photographs do not indicate the existence of any other satellite than the one discovered by Lassell.



Photograph of the Region of Hind's Variable Nebula in Taurus.
By Isaac Roberts, F.R.S.

In November last year Mr. Burnham, of the Lick Observatory, drew my attention to the region of Hind's Variable Nebula in Taurus, and informed me that he had searched the region with the 36-in. refractor and found what appeared to be a small star placed within a very small condensed nebula, the nebula being elongated in the direction of 151°·7. A rough reading of the wires gave 4″·4 for the length of the nebula.*

The photograph does not show any nebulosity or nebula or nebulous star anywhere about the region here referred to, though the exposure extended during three hours, and therefore nebulosity of a much fainter character than that shown in the *Pleiades* should have appeared on the photograph.

I am not suggesting that there can be any error in the observations made at the Lick Observatory, but the absence of any trace of nebulosity on the photograph may point to some rapid

* *Monthly Notices, R.A.S.*, vol. li. p. 94.

changes having taken place in the object between October 15, 1890, when observed at Lick, and December 9, when the photograph was taken. I am sending a copy of the photograph to Mr. Burnham, with the object of assisting to clear up what is now obscure.

The position of the nebula and of Hind's variable (R.A. $4^h\ 14^m\ 58^s$, D+19° 14′) is indicated within the larger of the white circles drawn on the photograph, and within the smaller white circle is the planet *Neptune* shown with its satellite.

The satellite is very strongly imprinted on the film of the negative as a black spot, and this is itself an indication of the faintness of the luminosity required to make an impression on the photograph.

Photograph of the cluster 44 *M. Cancri* (*the Præsepe*). By Isaac Roberts, F.R.S.

The photograph now presented is an enlargement to three and a half times from a negative which was taken on February 13, 1891, and is intended to serve as a chart of the stars between R.A. $8^h\ 30^m$ and $8^h\ 38^m$, declination N. 19° 19′ to 21° 19′, covering four square degrees of the sky. The exposure was given during ninety minutes in the 20-in. reflector. The negative shows many faint stars that cannot be copied on the enlarged photograph, and I propose to engrave (direct from the negative) this and some other clusters, as illustrations of the advantage of the engraving process over the photographic in showing all the stars, including the faintest, that may be on any negative and in eliminating from the chart specks on the film that would in any photo-printing process appear as, and be mistaken for, stars.

The photographs illustrating the above three communications are placed in the Library.

On the character of the chief line of the Nebula in Orion.
By Kavasgee D. Naegamvala, M.A.

Mr. Lockyer bases the claim of the chief nebula line to belong to magnesium, on the ground first that according to his observations it is exactly coincident with the first magnesium fluting, and secondly that it has the character not only of the remnant of a fluting, but of the fluting of magnesium, inasmuch as the line has been observed by him and by others to be *less* well defined on the violet side than on the red.

The recent researches of Dr. and Mrs. Huggins, followed by those of Mr. Keeler, have shown that the claim of perfect coincidence with the first magnesium fluting advanced by Mr. Lockyer for the chief nebula line is not tenable, while the fluted character of the line itself has been very much called in question of late.

Mr. Lockyer in his "Meteoritic Hypothesis" states that "observations of nebulæ should show that a fluting and not a line is in question," and as for instrumental means to be employed for this particular purpose he remarks that "high dispersion is not so likely to show the fluted character of the chief line as low."

I have therefore felt that the instrumental means at my disposal were well suited for a determination of the *character* of the line in question, and I have with that view examined the *Orion* nebula on numerous occasions during the last two months.

The telescope employed has been a silver-on-glass Newtonian by Sir Howard Grubb of 16½-inch aperture, while three different spectroscopes have been successively brought to bear upon the nebula. The first one employed was a direct-vision McClean Spectroscope, by Browning, with a slit opening only in one direction; while the second instrument was a rain-band spectroscope by Negretti and Zambra, provided with an eye-piece and easily, though not very widely, separating the D line; the slit of this spectroscope was also made to open only in one direction. The third spectroscope was a star single prism spectroscope by Grubb of his well-known form, with this difference, that, instead of the usual compound prism, a large prism of flint was substituted; the lenses of this spectroscope are an inch and a half in diameter, the telescope is provided with a battery of four eye-pieces, and the slit opens equally in both directions. The instrument gives spectra of exceptional brilliancy and of great definition.

Neither of the three spectroscopes has revealed any "fluted" characteristics in the chief line. On several occasions the line was observed not only well defined but *very sharp* and clear cut, having all the characteristics of a line proper; while any want of definition or clearness—in other words, the existence of any

raggedness—on one side was accompanied by a similar appearance on the other. The slit of the rain-band spectroscope was turned through 180° without changing the character of the line. With the Grubb spectroscope the whole battery of eye-pieces was successively employed and the width of the slit was varied through the fullest extent. Any widening of the slit invariably broadened the line *equally* in both directions *without any falling off in intensity on the violet side*, and in this particular the other two lines behaved precisely in the same fashion as the "chief line," all three being in the same field of view.

After a most careful examination, therefore, of the line in question, I have been forced to come to the conclusion that it does *not* reveal to me the character of "the remnant of a fluting" of magnesium.

I propose shortly to examine the chief line of the nebula from the point of view of coincidence by the siderostatic method.

College of Science, Poona:
1891 *March* 20.

Erratum in Radcliffe Observations of Iris Comparison Star.

Arg. Z. + 20°, 341 (*Monthly Notices*, vol. xlix. 7. p. 392 and p. 396).
For 69° 9′ 1″·59 *read* 69° 9′ 3″·55.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LI. JUNE 12, 1891. No. 8

Lieut.-General J. F. TENNANT, R.E., C.I.E., F.R.S., President, in the Chair.

Richard Edward Synge Cooper, Hillmorton Paddox, Rugby;
Hugh Frank Newall, M.A., Trinity College, Cambridge;
Samuel H. Ridge, B.A., F.R.G.S., 275 Victoria Parade East, Melbourne, Victoria;

were balloted for and duly elected Fellows of the Society.

The following candidate was proposed for election as a Fellow of the Society, the name of the proposer from personal knowledge being appended:—

Lord Edward Spencer Churchill, Castlemead, Windsor (proposed by the Earl of Rosse).

Seventy-eight presents were announced as having been received since the last meeting, including amongst others:—

W. Harkness, The Solar Parallax and its Related Constants, including the Figure and Density of the Earth, presented by the U. S. Naval Observatory; Harvard College Observatory, Variable Stars of Long Period, presented by the Observatory; O. A. L. Pihl, The Stellar Cluster χ *Persei* Micrometrically Surveyed, presented by the author; Observations of the Total Eclipse of the Sun, 1889, January 1, made by the Washington Observatory party, presented by the Observatory; H. Raper, The Practice of Navigation and Nautical Astronomy, 19th edition, presented by the publishers; Cincinnati Observatory, Charts and Micrometrical Measures of Nebulæ, presented by the Observatory; Siddhanta Siromani (Hindu Astronomy), presented by Col. Waterhouse; Pulkowa Observatory, Supplément aux Observations: Catalog von 5634 Sternen, von H. Romberg, presented

by the Observatory; J. Kleiber, On the Determination of the Orbits of Meteor-Streams [in Russian], with an abstract in English, presented by the author.

Researches on the Mean Density of the Earth. By Prof. A. Cornu.

On the invitation of the President, M. A. Cornu gave the following brief account of the experiments he has been making for some years past with M. J. B. Baille in order to measure the constant of Newtonian attraction, or of the mean density of the earth :—

L'appareil, analogue à celui de Cavendish, Baily et Reich, est fondé sur l'emploi de la balance de torsion; il est formé d'un levier horizontal (tube d'aluminium) suspendu à un long fil de torsion (4 mètres); il porte à ses extrémités les deux boules attirées (en cuivre, bismuth, fer ou platine) et en son milieu un miroir vertical réfléchissant les traits d'une échelle millimétrique placée à 5 mètres; deux masses attirantes (de mercure) produisent un couple de torsion dont on peut inverser le sens, ce qui double l'effet. Les déplacements de l'échelle, observés avec une lunette, mesurent les déplacements angulaires du levier.

Les principaux perfectionnements apportés à l'appareil primitif sont les suivants :

1°. *Le levier est reduit* à $0^{m}{\cdot}50$ c.-à-d. *au quart de la longueur* adoptée par Cavendish, Baily et Reich; l'appareil étant quatre fois moins long peut être renfermé dans un espace plus étroit et plus uniforme de température. La diminution du levier a encore un autre avantage en vertu du théorème suivant: Toutes choses égales d'ailleurs (masses attirantes, masses attirées, distance des masses attirantes aux masses attirées, durée d'oscillation du levier), la déviation par l'attraction newtonienne, indépendante des masses suspendues, est en raison inverse de la longueur du levier.

2°. *Les masses attirantes* ont pu alors être *réduites* à 10 *kilogrammes* sans cesser de donner des déviations mesurables à $\frac{1}{500}$ près, ce qui facilite beaucoup la manœuvre de l'inversion (les masses attirantes de Cavendish dépassaient 140 livres). De plus pour éviter les chocs inévitables dans le déplacement des masses, on a remplacé le plomb par du mercure. A l'aide d'une aspiration convenable, on fait passer ce liquide dans des sphères creuses en fonte sans la moindre trépidation.

3°. *La loi complète des oscillations du levier est enregistrée* sur un cylindre enfumé. A cet effet, l'observateur donne un *tap* sur une clef électrique au passage des divisions de l'échelle sous le réticule de la lunette : divers artifices très simples établissent la concordance des divisions observées et des signaux enregistrés. On peut ainsi vérifier que les oscillations du levier satisfont à la loi

$$x = Ae^{-\alpha t} \sin 2\pi \frac{t-to}{T}$$

qui est l'intégrale de l'équation différentielle du mouvement de rotation d'un système solide soumis à *deux espèces de forces seulement*: 1° les unes proportionnelles au déplacement (torsion, variation de distance des masses en présence etc.), dont la résultante constitue la force équilibrant l'attraction et qu'il importe de déterminer avec précision; 2°, les autres, proportionnelles à la vitesse (amortissement par l'air, par le frottement intérieur du fil de torsion etc.) qui interviennent comme influence perturbatrice.*

4°. *Le fil de torsion doit être recuit* en le maintenant suivant une direction sensiblement rectiligne avant de l'ajuster au levier de la balance. On élimine ainsi toutes les anomalies qui se présentent dans les balances de torsion (instabilité du zéro, déplacement continu avec le temps etc.) et qui proviennent vraisemblablement de l'état moléculaire forcé imprimé au fil par l'écrouissage et l'enroulement antérieur sur une bobine.

5°. *Le levier de la balance de torsion doit être en communication métallique avec la boîte conductrice qui l'enveloppe et avec le sol.* On évite ainsi les perturbations qui proviennent des variations de potentiel électrostatique de l'air et des supports, du haut en bas de l'appareil.

6°. *La boîte protectrice du levier de la balance de torsion doit être en métal bon conducteur et d'épaisseur assez grande.* En effet les variations accidentelles de température d'un point à l'autre de la boîte produisent des courants d'air qui se traduisent par des efforts hydrodynamiques d'un ordre de grandeur considérable et affectant une allure très régulière. Ainsi, une bougie allumée placée à quelques centimètres du levier protégé par une boîte de zinc mince attire énergiquement la boule la plus voisine: on a pu ainsi répéter toutes les expériences du radiomètre de M. Crookes avec cette différence, que l'action apparente d'un corps chaud est ici une attraction au lieu d'une répulsion. La substitution à la boîte en zinc mince d'une boîte en cuivre rouge, épaisse de 3 millimètres, a fait disparaître ces phénomènes singuliers: la grande conductibilité calorifique du cuivre pur empêche la localisation de la chaleur transmise et par suite fournit l'équilibre continuel de température autour du levier.

Telles sont les principales précautions nécessaires pour parvenir à la régularité complète des observations: il ne reste plus maintenant, pour arriver au chiffre définitif, qu'à effectuer un petit nombre d'expériences accessoires destinées à estimer l'approximation assignable aux mesures.

* Ce mode d'enregistrement est assez précis pour qu'on ait pu mettre en évidence, mesurer et éliminer l'influence d'un troisième genre de force, introduit à dessein (action proportionnelle au carré du déplacement.)

Observations of the Moon made at the Radcliffe Observatory, Oxford, during the year 1890; *and a Comparison of the Results with the Tabular Places from Hansen's Lunar Tables.* By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

The present paper contains the observations of the right ascensions and north polar distances of the Moon, made at the Radcliffe Observatory during the year 1890. These results are here compared with those deduced from Hansen's Lunar Tables on two suppositions:—

(1) That the mean times, found in the usual way from the sidereal times at mean noon, given in the *Nautical Almanac*, were *not* changed in 1864 by the adoption of a different unit of time.

(2) That these mean times *were* changed in 1864 by the adoption of a different unit of time to fix the positions of the clock stars relatively to the Sun, in accordance with the views which I have explained in papers communicated to the Society.

In the Appendix to the *Monthly Notices*, vol. l., will be found the results of a comparison between the Greenwich Lunar Observations, 1847–1861, and Hansen's Tables, of greater accuracy than had before been available for use; and these results have been utilised to form the mean results given in Table III.

An examination of the residual errors shows that the motion of the Moon was closely represented by Hansen's Tables during the period 1847–1863, although periodical errors of no inconsiderable amount, due either to defects of theory or to imperfections in the practical methods of comparing the theoretical and observational results, are shown to exist.

The mean annual error in longitude of Hansen's Tables from 1847 to 1863 is, however, only $-1''\cdot85$, and no law of regular increase is apparent; but Table III. shows that when the time, t, is found as at present, the mean annual error has increased since 1863 at an average rate of $0''\cdot72$ per annum, and that the error now amounts to $+18''$. The mean annual error of Hansen's Tables from 1864 to 1890 taken out with the *corrected* argument is $-1''\cdot44$, which differs but very slightly from the mean error between 1847 and 1863.

For facilities for an accurate comparison between Hansen's Lunar Tables and Observations, I am again indebted to the places published in the *Connaissance des Temps.*

TABLE I.

Radcliffe Observations of the Moon, 1890.

R.A.'s and N.P.D.'s of the Centre of the Moon, 1890; *compared with Hansen's Tabular Places*, **Uncorrected** *and* **Corrected** *for the change in the Unit of Mean Time introduced in the year* 1648.

Day, 1890.	Correction to be subtracted from M.T. for change of Sidereal Time at Mean Noon since 1854.	Observer.	Limb observed in N.P.D.	Observed R.A.	R.A. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**	Limb observed in R.A.	Observed N.P.D.	N.P.D. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**
	s			h m s	s	s	s	s		° ′ ″	″	″	″	″
Jan. 8	38·60	R.	II.	9 34 16·09	16·95	+0·86	−1·30	−0·44	S.	71 29 8·77	13·35	+4·58	−5·00	−0·42
29	38·68	F. B.	I.	4 2 52·33	53·42	+1·09	−1·32	−0·23	S.	71 57 20·43	18·55	−1·88	+5·30	+3·42
Feb. 3	38·70	F. B.	I.	8 25 54·85	55·89	+1·04	−1·36	−0·32	N.	68 1 33·21	34·95	+1·74	−3·09	−1·35
5	38·71	R.	II.	10 7 45·32	46·25	+0·93	−1·29	−0·36	S.	73 54 44·26	49·51	+5·25	−5·94	−0·69
9	38·72	R.	II.	13 19 31·07	31·92	+0·85	−1·26	−0·41	S.	93 7 45·60	53·89	+8·29	−8·28	+0·01
12	38·74	R.	II.	15 56 23·70	24·74	+1·04	−1·49	−0·45	S.	107 43 30·80	34·75	+3·95	−6·21	−2·26
27	38·80	W.	I.	5 27 22·82	23·82	+1·00	−1·38	−0·38	S.	67 28 23·70	20·99	−2·71	+2·78	+0·07
Mar. 3	38·81	W.	I.	8 59 17·54	18·63	+1·09	−1·34	−0·25	N.	69 26 29·47	32·16	+2·69	−4·20	−1·51
5	38·82	R.	I.	10 39 37·28	38·23	+0·95	−1·28	−0·33	N.	76 33 41·09	46·58	+5·49	−6·80	−1·31
8	38·83	R.	II.	13 4 9·58	10·49	+0·91	−1·27	−0·36	S.	91 37 20·64	28·09	+7·45	−8·46	−1·01
29	38·92	F. B.	I.	7 46 43·70	44·85	+1·15	−1·39	−0·24	N.	66 29 7·35	8·58	+1·23	−1·94	−0·71
31	38·92	R.	I.	9 30 27·77	28·75	+0·98	−1·32	−0·34	N.	71 4 40·36	44·60	+4·24	−5·16	−0·92
Apr. 1	38·93	R.	I.	10 20 20·80	21·68	+0·88	−1·29	−0·41	N.	74 46 58·88	63·41	+4·53	−6·46	−1·93
2	38·93	F. B.	I.	11 9 10·19	11·12	+0·93	−1·27	−0·34	N.	79 13 51·56	57·13	+5·57	−7·50	−1·93

Day, 1890.	Correction to be subtracted from M.T. for change of Sidereal Time at Mean Noon since 1864.	Observer.	Limb observed in R.A.	Observed R.A.	R.A. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**	Limb observed in N.P.D.	Observed N.P.D.	N.P.D. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**
	s			h m s	s	s	s	s		° ′ ″	″	″	″	″
Apr. 3	38·94	W.	I.	11 57 27·03	28·18	+1·15	−1·27	−0·12	N.	84 14 48·81	56·43	+7·62	−8·24	−0·62
29	39·04	R.	I.	10 48 42·24	42·99	+0·75	−1·27	−0·52	N.	77 5 33·65	39·50	+5·85	−7·10	−1·25
30	39·04	F. B.	I.	11 36 44·61	45·63	+1·02	−1·26	−0·24	N.	81 53 12·74	20·37	+7·63	−7·99	−0·36
May 1	39·05	W.	I.	12 24 47·32	48·30	+0·98	−1·27	−0·29	N.	87 9 29·05	34·32	+5·27	−8·60	−3·33
2	39·05	R.	I.	13 13 44·07	44·91	+0·84	−1·31	−0·47	N.	92 42 18·69	24·97	+6·28	−8·85	−2·57
11	39·09	R.	II.	22 13 13·09	14·50	+1·41	−1·50	−0·09	N.	106 5 18·34	10·46	−7·88	+7·33	−0·55
26	39·15	F. B.	I.	10 28 43·98	45·01	+1·03	−1·27	−0·24	N.	75 8 58·08	61·87	+3·79	−6·60	−2·81
31	39·17	F. B.	I.	14 32 18·03	19·20	+1·17	−1·41	−0·24	N.	101 4 29·58	37·57	+7·99	−8·41	−0·42
June 6	39·19	W.	II.	20 52 54·41	56·23	+1·82	−1·67	+0·15	N.	111 29 19·07	14·47	−4·60	+5·02	+0·42
26	39·27	W.	I.	13 18 14·32	15·12	+0·80	−1·27	−0·47	N.	93 6 58·65	64·52	+5·87	−8·65	−2·78
27	39·28	R.	I.	14 7 35·84	36·80	+0·96	−1·34	−0·38	N.	98 32 18·93	25·39	+6·46	−8·50	−2·04
July 3	39·30	F. B.	II.	20 23 30·23	32·05	+1·82	−1·77	+0·05	N.	112 46 21·55	17·77	−3·78	+4·05	+0·27
28	39·40	R.	I.	17 31 33·40	34·65	+1·25	−1·72	−0·47	N.	113 19 7·04	10·51	+3·47	−3·32	+0·15
Aug. 1	39·42	R.	II.	22 0 54·60	56·08	+1·48	−1·65	−0·17	N.	107 3 8·74	0·93	−7·81	+7·70	−0·11
5	39·43	R.	II.	1 44 25·32	26·67	+1·35	−1·37	−0·02	N.	83 45 19·64	11·53	−8·11	+9·01	+0·90
7	39·44	W.	II.	3 27 21·00	22·41	+1·41	−1·38	+0·03	N.	73 43 57·18	51·41	−5·77	+6·72	+0·95
23	39·50	R.	I.	16 4 50·19	51·32	+1·13	−1·50	−0·37	N.	109 12 11·18	16·04	+4·86	−6·05	−1·19
29	39·53	W. I. & II.		22 30 12·06	13·72	+1·66	−1·62	+0·04	S.	104 34 34·53	26·19	−8·34	+8·63	+0·29

Day, 1890.	Correction to be subtracted from M.T. for change of Sidereal Time at Mean Noon since 1864.	Observer.	Limb observed in R.A.	Observed R.A.	R.A. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**	Limb observed in N.P.D.	Observed N.P.D.	N.P.D. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**
	s			h m s	s	s	s	s		° ′ ″	″	″	″	″
Sept. 4	39·55	F. B.	II.	3 59 52·75	54·25	+1·50	−1·43	+0·07	N.	71 1 44·64	40·07	−4·57	+5·91	+1·34
22	39·62	R.	I.	18 47 44·62	46·06	+1·44	−1·71	−0·27	S.	114 57 4·31	3·69	−0·62	+0·03	−0·59
25	39·64	F. B.	I.	22 0 6·97	8·59	+1·62	−1·62	0·00	S.	107 11 65·54	59·99	−5·55	+7·72	+2·17
27	39·64	F. B.	I.	23 57 11·30	12·83	+1·53	−1·49	+0·04	S.	95 42 25·05	17·76	−7·29	+10·09	+2·80
30	39·66	R.	II.	2 40 47·14	48·27	+1·13	−1·44	−0·31	N.	77 26 9·26	1·21	−8·05	+8·46	+0·41
Oct. 1	39·66	F. B.	II.	3 35 17·80	19·22	+1·42	−1·46	−0·04	N.	72 35 64·19	58·55	−5·64	+6·90	+1·26
21	39·74	R.	I.	20 35 29·12	30·51	+1·39	−1·66	−0·27	S.	112 43 9·27	4·10	−5·17	+4·54	−0·63
28	39·77	W.	II.	3 8 23·42	25·01	+1·59	−1·46	+0·13	N.	74 44 59·34	52·18	−7·16	+7·87	+0·71
Nov. 2	39·79	R.	II.	7 49 25·01	25·99	+0·98	−1·45	−0·47	S.	65 32 43·25	43·38	+0·13	−2·27	−2·14
21	39·86	R.	I.	0 7 28·21	29·64	+1·43	−1·41	+0·02	S.	94 43 49·91	41·14	−8·77	+9·80	+1·03
24	39·88	W.	I.	2 44 32·89	34·13	+1·24	−1·43	−0·19	S.	76 59 60·35	52·69	−7·66	+8·42	+0·76
25	39·88	W.	I.	3 38 44·83	46·13	+1·30	−1·47	−0·17	S.	72 11 20·62	15·59	−5·03	+6·96	+1·93
26	39·88	R.	II.	4 34 34·79	35·82	+1·03	−1·51	−0·48	S.&N.	68 24 47·36	42·74	−4·62	+5·10	+0·48
Dec. 25	40·00	W.	I.&II.	6 5 48·64	50·09	+1·45	−1·53	−0·08	N.	65 2 56·44	54·04	−2·40	+1·62	−0·78
						s		s				″		′
Mean of Errors, without regard to sign ...				...	...	**1·191**	...	**0·256**		...	...	**5·297**	...	**1·208**
Mean Errors for the Year				... ...	...	**+1·191**	...	**−0·233**						

TABLE II.

Radcliffe Observations of the Moon, 1890.

Errors of the Moon's Tabular Place in Longitude and Ecliptic Polar Distance, **Uncorrected** *and* **Corrected** *for the Change in the Unit of Mean Time introduced in the year* 1864.

Day, 1890.	Observer.	Limb observed in R.A.	Limb observed in N.P.D.	Errors of Longitude (Hansen *minus* Observed). Uncorrected.	Errors of Longitude (Hansen *minus* Observed). Corrected.	Errors of E.N.P.D. (Hansen *minus* Observed). Uncorrected.	Errors of E.N.P.D. (Hansen *minus* Observed). Corrected.
Jan. 8	R.	II.	S.	+13".09	−6".08	+0".41	+1".61
Jan. 29	F.B.	I.	S.	+15·65	−3·89	+1·16	+2·72
Feb. 3	F.B.	I.	N.	+14·49	−4·65	−1·74	−0·26
5	R.	II.	S.	+14·44	−5·11	+0·19	+1·18
9	R.	II.	S.	+14·98	−5·71	+2·90	+2·31
12	R.	II.	S.	+15·37	−6·77	+0·82	−0·89
Feb. 27	W.	I.	S.	+13·98	−5·26	−1·93	−0·22
Mar. 3	W.	I.	N.	+15·49	−3·80	−1·70	−0·47
5	R.	I.	N.	+14·95	−4·97	−0·12	+0·60
8	R.	II.	S.	+15·49	−5·38	+1·64	+1·14
Mar. 29	F.B.	I.	N.	+15·80	−3·38	−1·61	−0·11
31	R.	I.	N.	+14·57	−4·88	−0·38	+0·65
Apr. 1	R.	I.	N.	+13·56	−6·25	−0·39	+0·35
2	F.B.	I.	N.	+14·85	−5·39	−0·22	+0·18
3	W.	I.	N.	+18·85	−1·90	+0·13	+0·15
Apr. 29	R.	I.	N.	+12·41	−7·53	+1·24	+1·73
30	F.B.	I.	N.	+17·01	−3·43	+0·98	+1·09
May 1	W.	I.	N.	+15·69	−5·35	−0·98	−1·34
2	R.	I.	N.	+14·09	−7·52	+1·14	+0·29
11	R.	II.	N.	+21·90	−1·02	−0·10	−0·98
May 26	F.B.	I.	N.	+15·33	−4·28	−1·97	−1·33
31	F.B.	I.	N.	+18·91	−3·49	+2·18	+0·71
June 6	W.	II.	N.	+25·74	+1·90	+2·49	+0·97
June 26	W.	I.	N.	+13·37	−7·60	+0·92	+0·08
27	R.	I.	N.	+15·64	−6·02	+1·25	−0·01
July 3	F.B.	II.	N.	+25·44	+0·61	+2·22	+0·42

Day, 1890.	Observer.	Limb observed in R.A.	Limb observed in N.P.D.	Errors of Longitude Hansen (*minus* Observed). Uncorrected.	Corrected.	Errors of N.P.D. Hansen (*minus* Observed). Uncorrected.	Corrected.
July 28	R.	I.	N.	+17″·36	−6″·46	+2″·62	+0″·47
Aug. 1	R.	II.	N.	+22·70	−2·26	+0·03	−0·95
5	R.	II.	N.	+21·75	−0·60	−0·34	+0·73
7	W.	II.	N.	+21·13	+0·18	−0·61	+1·03
Aug. 23	R.	I.	N.	+16·65	−5·37	+1·67	−0·15
29	W.	I. & II.	S.	+25·57	+0·43	+1·15	+0·48
Sept. 4	F.B.	II.	N.	+21·78	+0·71	−0·23	+1·51
Sept. 22	R.	I.	S.	+19·58	−3·61	+1·01	−0·89
25	F.B.	I.	S.	+23·78	−0·75	+2·83	+2·03
27	F.B.	I.	S.	+23·95	−0·58	+2·45	+2·81
30	R.	II.	N.	+18·25	−4·45	−2·60	−1·00
Oct. 1	F.B.	II.	N.	+21·09	−0·85	−0·72	+1·09
Oct. 21	R.	I.	S.	+19·98	−3·79	−0·17	−1·55
28	W.	II.	N.	+24·10	+1·62	−0·63	+1·20
Nov. 2	R.	II.	S.	+13·41	−6·71	−2·33	−0·92
Nov. 21	R.	I.	S.	+23·27	−0·14	+0·48	+1·07
24	W.	I.	S.	+19·61	−2·88	−1·85	−0·11
25	W.	I.	S.	+19·22	−2·81	−0·59	+1·31
26	R.	II.	S. & N.	+14·91	−6·70	−2·47	−0·50
Dec. 25	W.	I. & II.	N.	+19·70	−1·10	−2·57	−0·77
Mean of Errors, without regard to sign ...			... ...	18″·019	3″·786	1″·264	0″·921
Mean Errors for Year			... ...	+18″·019	−3″·549	...	...

Observers: W., Mr. W. Wickham; R., Mr. W. H. Robinson; F.B., Mr. F. A. Bellamy.

TABLE III.

Mean Excess over Observation of the Moon's Tabular Place in Longitude for the years 1847 to 1890, as Computed from Hansen's Tables.

Uncorrected *and* **Corrected** *for the change in the Unit of Mean Time introduced in the year 1864.*

Year.	Errors of Longitude (Hansen *minus* Observed).	
	Uncorrected.	**Corrected.**
	″	″
1847	+ 0·51	+0·51
1848	− 0·53	−0·53
1849	− 1·08	−1·08
1850	− 0·97	−0·97
1851	− 1·93	−1·93
1852	− 1·57	−1·57
1853	− 2·18	−2·18
1854	− 2·34	−2·34
1855	− 1·40	−1·40
1856	− 1·51	−1·51
1857	− 2·41	−2·41
1858	− 2·61	−2·61
1859	− 2·49	−2·49
1860	− 3·62	−3·62
1861	− 2·95	−2·95
1862	− 2·83	−2·83
1863	− 1·61	−1·61
1864	+ 0·12	−0·81
1865	+ 1·27	−0·22
1866	+ 2·14	−0·22
1867	+ 3·48	+0·36
1868	+ 4·12	+0·28
1869	+ 4·28	−0·35
1870	+ 4·83	−0·66
1871	+ 6·96	+0·44
1872	+ 7·31	+0·10
1873	+ 8·24	+0·20
1874	+ 9·29	+0·56
1875	+ 9·87	+0·36
1876	+ 9·80	−0·50
1877	+ 9·23	−1·90
1878	+ 8·22	−3·60
1879	+ 9·63	−3·12
1880	+10·89	−2·77
1881	+10·51	−4·06
1882	+12·68	−2·51
1883	+14·71	−1·50
1884	+14·65	−1·91
1885	+15·20	−1·82
1886	+15·34	−2·53
1887	+15·70	−3·25
1888	+17·68	−2·46
1889	+17·37	−3·51
1890	+18·02	−3·55

1847 to 1879: Greenwich observations. 1880 to 1882: Mean of Greenwich and Radcliffe. 1883 to 1890: Radcliffe observations.

Radcliffe Observatory, Oxford:
1891 *June* 10.

Preliminary Note on the Change of Personal Equation with Stellar Magnitude in Transits observed with the Transit Circle at the Royal Observatory, Greenwich. By W. H. M. Christie, M.A., F.R.S., Astronomer Royal.

The question of the determination of the variation of personal equation with the magnitude of the star observed has been lately brought prominently forward by Professor Auwers in connection with the Greenwich observations of *Victoria* and *Sappho* and comparison stars in 1889, now being discussed by him. I had hoped to have used the Personal Equation Machine for this investigation, this being one of the objects for which it was originally intended, but as special photometric arrangements would have to be devised, it was judged best, in order to avoid delay, to determine the change of personal equation in observations of stars with the transit circle, when screens of fine wire gauze were placed in front of the object-glass to obscure the stars' light. The screens used were marked *a*, *b*, *e*, *f*, and *g*, the first three being made of fine brass wire, and the last two of coarser iron wire. The size of the meshes, which are approximately square, and the thickness of the wires, were measured with a micrometer microscope for each of these screens, and the results are given in the following table.

	Screen *a*.	*b*.	*e*.	*f*.	*g*.
	mm.	mm.	mm.	mm.	mm.
Side of squares of mesh...	0·45	0·52	0·39	1·08	1·21
Thickness of wire ...	0·12	0·13	0·13	0·34	0·30

As the star entered the field of the telescope, the object-glass was covered successively by one or other of these screens, or by two screens superposed, the observer then making estimations of the apparent magnitude of the stars, whose light was thus diminished. The accuracy of these estimations was tested by the comparison of the magnitude given in the Greenwich Ten-Year Catalogue, or in the British Association Catalogue, with similar estimations of magnitude, either (1) with the object-glass unscreened, when the estimated magnitude should agree with the tabular, or (2) when card diaphragms, with circular apertures of $5\frac{1}{8}$ and $3\frac{1}{4}$ inches diameter respectively, were placed over the object-glass, so that the estimated magnitudes should differ by 1·0 and 2·0 magnitudes respectively from the tabular. The mean results of these estimations for each observer, and for each screen, diaphragm, or pair of screens, are given in Table I. It will be seen from the estimations with full aperture, and with diaphragms *c* and *d*, that all the observers agree in estimating the magnitude as numerically too large, and that

this excess is larger the smaller the apparent star is. We may say from this that the screens a, b, and e each diminish the brightness by between 1·5 and 2·0 magnitudes.

As a star approached the transit wires, the object-glass was covered with a screen, and the transit recorded over the first four wires; the screen was then removed, and the transit over the last four wires was recorded with full aperture of object-glass. For the next star the order of these operations was reversed, that is, the first four wires were observed with full aperture, and the last four with the screen. The excess of the time of transit, reduced to centre wire, with screened object-glass over the time with unscreened, was then tabulated. The means of the results of these observations for each observer, and for each screen or pair of screens, are given in Table II. Since it appears from Table I. that the values of screens a, b, and e are approximately the same, as are also those of f and g, the observations by each observer with screens a, b, and e, with f and g, and with the pairs $\overline{a+b}$, $\overline{a+e}$, $\overline{b+e}$ have been taken together, and then grouped according to the magnitudes of the stars observed. The results of this grouping are given in Table III. As far as they go they indicate that there is a general tendency with all the observers to observe stars with object-glass screened later, and that this is more marked in the case of the fainter stars. It will be remarked that the general mean, when the brightness is reduced nearly four magnitudes by means of two screens, is less than the general mean when only one screen is used, instead of being nearly double, as it should be theoretically. The comparative paucity of observations with two screens superposed may, to some extent, account for this anomalous result, but it is not unlikely that the observers may have been influenced by the peculiar character of the diffraction image equally with one screen and with two. It is not clear that the results indicate a real change of personal equation in observations of fainter stars, as the introduction of the screen modifies the image of the star, and this modification of the image may give rise to a change of personal equation unconnected with the diminution of brightness.

TABLE I.

Table of Difference of Estimated and Tabular Magnitudes by each Observer when the Star is seen with full aperture and with each diaphragm and each screen.

	No. of Obs.	A.D. Mag.	No. of Obs.	T. Mag.	No. of Obs.	L. Mag.	No. of Obs.	H. Mag.	Means Mag.
Full aperture	89	+0·20	67	+0·37	103	+0·08	157	+0·05	+0·14
Screen *a*	65	+2·46	40	+2·15	93	+1·76	97	+2·00	+2·05
Screen *b*	59	+2·15	44	+2·00	88	+1·51	97	+1·79	+1·81
Screen *e*	51	+2·68	43	+2·16	93	+1·98	75	+2·11	+2·18
Screen *f*	23	+1·91	7	+1·24	7	+1·43	16	+1·49	+1·63
Screen *g*	20	+1·86	8	+1·23	7	+1·14	18	+1·52	+1·55
Screen $\overline{a+b}$	18	+3·99	24	+3·80	27	+3·28	23	+3·73	+3·66
Screen $\overline{a+e}$	8	+4·20	21	+3·75	25	+3·67	6	+4·32	+3·83
Screen $\overline{b+e}$	4	+3·78	20	+3·80	26	+3·44	6	+3·65	+3·62
Diaphragm *c* $3\frac{1}{4}$ inches...	53	+2·56	36	+2·33	80	+1·88	85	+2·07	+2·15
Diaphragm *d* $5\frac{1}{8}$ inches...	61	+1·54	39	+1·74	87	+1·17	94	+1·21	+1·34

TABLE II.

Excess of Observed Time of Transit with Screen over Observed Time with Full Aperture.

Observer.	Screen a. No. of Obs.	s	Screen b. No. of Obs.	s	Screen c. No. of Obs.	s	Screen $\overline{a+b}$. No. of Obs.	s	Screen $\overline{a+c}$. No. of Obs.	s
A.D.	27	+0·027	26	+0·020	20	+0·016	5	+0·030	1	+0·050
T.	11	+0·034	9	+0·036	12	+0·062	7	+0·057	6	+0·007
L.	20	+0·026	23	+0·013	13	+0·053			3	−0·040
H.	38	+0·036	41	+0·036	24	+0·028	5	+0·064	2	−0·005
Means		+0·031		+0·026		+0·035		+0·051		−0·003

Observer.	Screens $\overline{b+c}$. No. of Obs.	s	Screens $\overline{a+b+c}$. No. of Obs.	s	Screen f. No. of Obs.	s	Screen g. No. of Obs.	s
A.D.	3	−0·013	1	+0·020	7	0·000	4	+0·023
T.	4	+0·048	2	+0·050			2	−0·040
L.	2	−0·060			1	0·000		
H.					7	+0·004	5	+0·056
Means		+0·004		+0·040		+0·002		+0·027

TABLE III.

Excess of Observed Time of Transit with Screen over Observed Time with Full Aperture arranged according to Magnitude of Star.

Screen a, b, or c diminishing the brightness by nearly 2 magnitudes.

Magnitude of Stars.	A.D. No. of Obs.	A.D. Mean Diff. s	T. No. of Obs.	T. Mean Diff. s	L. No. of Obs.	L. Mean Diff. s	H. No. of Obs.	H. Mean Diff. s
0−3·9	14	+0·036	5	+0·022	11	−0·007	6	+0·015
4·0−4·9	13	+0·022	8	+0·016	10	+0·035	9	+0·034
5·0−5·9	22	+0·014	13	+0·064	30	+0·039	25	+0·023
6·0−6·9	14	+0·013	4	+0·067	4	+0·008	38	+0·033
7·0 and fainter	8	+0·051	1	+0·070	1	+0·020	24	+0·052
Means	71	+0·024	31	+0·045	56	+0·025	102	+0·034

General Mean +0s·031.

Screens $\overline{a+b}$, $\overline{a+c}$, or $\overline{b+c}$ diminishing the brightness by about 3·7 magnitudes.

Magnitude of Stars.	A.D. No. of Obs.	A.D. Mean Diff. s	T. No. of Obs.	T. Mean Diff. s	L. No. of Obs.	L. Mean Diff. s	H. No. of Obs.	H. Mean Diff. s
0−3·9	6	−0·023	5	+0·036	2	−0·045	2	−0·005
4·0−4·9	3	+0·100	5	+0·064	3	−0·050	3	+0·030
5·0 and fainter			7	+0·022			2	+0·115
Means	9	+0·018	17	+0·038	5	−0·048	7	+0·044

General Mean +0s·023.

The Motion of 20 Draconis. By S. W. Burnham.

Although this double star (Σ 2118) was discovered by William Herschel more than one hundred years ago, it has received but little attention from observers in recent years. Within the last thirty years it has been close and rather difficult, but before 1860 it was easily measurable with almost any telescope. During this period the distance was slowly diminishing, while the angle remained nearly constant. For the past ten years it has been too close to be seen with any but the most powerful refractors.

I have collected all the observations with the micrometer which have any value, and give them below in chronological order for convenience in future investigations. I have omitted all negative results where the star was noted as "round," "single," "elongated," &c., since it is evident that it has never been really single, and the failures to see it were due to insufficient optical power, or unfavourable atmospheric conditions.

1783·26	251°·5	...	♅	1*n*
1830·32	242·6	0·63	H	1*n*
1831·37	246·1	0·70	H	1*n*
1832·30	246·4	0·85	⧖	5*n*
1834·57	252·0	...	Da	1*n*
1836·75	247·0	0·71	⧖	3*n*
1840·77	242·9	...	Da	1*n*
1841·24	245·3	0·77	O⧖	3*n*
1843·32	248·4	0·8	Ma	1*n*
1847·71	243·3	...	Mh	2*n*
1847·97	244·6	0·65	Ma	2*n*
1854·81	241·7	0·61	Da	3*n*
1857·35	240·1	0·37	Se	3*n*
1859·67	235·7	0·58	O⧖	2*n*
1872·42	238·0	0·27	O⧖	1*n*
1874·73	224·0	...	N	1*n*
1877·13	229·4	0·28	De	3*n*
1880·82	211·3	0·20	*β*	4*n*
1889·45	140·7	0·11	*β*	3*n*
1891·33	125·6	0·11	*β*	3*n*

All of these measures are laid down accurately to scale on the accompanying diagram, except the observations of Herschel, Dawes, Mitchell, and Newcomb, where the distance was not measured. It is obvious at a glance that these positions taken together furnish no evidence whatever of orbital motion so far

as their direction is concerned. A straight line will better represent them than any curve. The chances are enormously in favour of this being a physical system, and I have no doubt that will be shown to be the fact, but at present it is more a matter of probability than anything else. If these stars were a considerable distance apart, there would be hardly any doubt that the relative movement was due to proper motion. The two components, as one star, have a proper motion of 0″·227 in the direction of 79°·3, and this angle corresponds very nearly to the motion of B with respect to A. A line drawn through the observed positions of B, making an angle of 73° with the meridian, will represent the measures as closely as they are ever represented by a line of any character in stars of this class. To be sure, the later observations appear to indicate an accelerated motion, as would be expected if the path is a very elongated ellipse, but the errors in the series generally are so large it is impossible to deduce any harmonious result. Taking the mean of Struve's measures to represent the place of B at the mean date (1834·5), the movement of that star to 1891·3 is 0″·86, giving an average of 0″·015 per annum. If it is moving around the primary, as is most probably the case, it is evident that the apparent ellipse is one of extraordinary elongation. There is nothing like it known in the heavens. The period is certainly several hundred years. In one or two years more, the measures will definitely settle the character of this motion. It will probably be a difficult object for some time to come, and should be carefully measured by observers having sufficiently powerful instruments.

It will be noticed that the same grouping of positions, and apparent reversal of motion, occurs here in the first eight measures, which I have shown elsewhere is found in the measured places of all slow-moving pairs.

Lick Observatory:
May 29.

The Companions to Regulus. By S. W. Burnham.

The distant companion to *Regulus* was first observed by Herschel I. in 1779, and catalogued as No. 11 of his Class VI. It was measured on one night, but the distance was about 8″ too small. In 1821 it was better observed by South and Herschel, but the accurate measures commence with the observations of Struve a few years later. The measures of the last fifty years show conclusively that this companion has the same proper motion as *Regulus*, which has a motion in space of 0″·267 annually in the direction of 274°·5. Since the measures of Struve

20 DRACONIS

S.W.Burnham, del.

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the large star has shifted its place nearly 14″. The following measures are sufficient to show the relative fixity of the two stars:

1781·84	305°·1	168″·33	H 1*n*
1821·21	307·3	174·90	Sh 2*n*
1836·24	306·6	176·90	Σ 5*n*
1863·18	306·8	176·06	En 3*n*
1864·78	306·6	176·89	De 5*n*
1891·34	306·8	176·73	β 4*n*

Winlock, when at the Harvard College Observatory, found that the old companion had a very minute attendant, which had escaped all previous observers. He does not seem to have measured it, and the first observation with the micrometer is in 1877 by Hall. The following are all the measures to this time:—

1877·75	86°·4	3″·48	Hl 5*n*
1878·14	88·5	3·29	β 4*n*
1880·15	87·7	3·03	β 1*n*
1890·27	85·7	3·05	β 3*n*
1891·34	88·2	3·05	β 3*n*

These observations show that there has been no change in the angle during this time, and probably none in the distance, and, therefore, the new companion is moving through space with the other stars, and the whole probably form one vast system. During the period covered by these measures, B has moved 3″·3 by virtue of its proper motion, and the distance of C at the end of this time would be increased by that amount provided the movement was not common to both stars.

With most telescopes the close pair would be difficult. My first two sets of measures were made with the Chicago 18½-inch refractor. Clark has seen it with a 12-inch object-glass, and that is probably about as small an aperture as it could be fairly seen with. In the course of time there will doubtless be some indications of orbital motion in B and C, but the distance between them is too large for any rapid movement.

Lick Observatory, May 15.

The Orbit of 36 *Andromedæ* (Σ 73). By T. Lewis.

	h	m	s	
R.A.	0	50	4	1890·0
N.P.D.	66°	58′	3″	

Some time ago, having drawn the apparent ellipse for this binary, I was surprised to find that the companion had passed ap-astron. According to Doberck's elements, computed in 1875, this should not occur till 1973. Collecting all the published observations, I carefully plotted them on millimètre paper, and found that a satisfactory curve could not be drawn through them. By comparing neighbouring observations, a systematic difference between the observers was very apparent. The final personal equations deduced were :—

H_2.	−0°·5 and	″·00	Ta.	+1°·5 and	+0″·3
Σ.	−0·5 „	·00	Har.	−0·5 „	−·05
Sm.	−0·5 „	−·02	Gld.	+0·6 „	+·05
Md.	−1·4 „	−·02	Dob.	−0·3	...
Da.	+1·2 „	+·05	Sch.	−0·3	...
OΣ.	0·0 „	−·05	W. & S.	−0·5 „	+·04
De.	+0·7 „	+·05	Hall.	−0·5	...
Sec.	−0·3 „	+·10	Eng.	+0·2 „	−·05

The quantities are applicable to the observations with the given sign. For other observers an equation either could not be deduced or the material was insufficient. After correcting the position-angles for precession to 1890, and also for the P.E.'s, they were again plotted and a curve drawn, from which an ellipse was computed according to the method of Herschel. These elements were then corrected by Klinkerfues' method and the definitive elements obtained.

P	137·5 years	Ω	123° 33′ (1890·0)
T	1819·7	λ	70° 0′
e	0·67	a	1″·09
γ	44° 30′	μ	2°·62

Doberck's period is 349 years.

Below is a comparison between the observations as corrected for P.E. and precession, and those computed from the above elements.

Epoch.	O	C	O−C	O	C	O−C	Observer.
	°	°	°	″	″	″	
1830·67	302·0	302·8	−0·8	0·72	0·81	−·09	H_2.
30·78	306·8	3·1	+3·7	·90	·81	+·09	H_2.
31·79	308·3	5·5	+2·8	·78	·83	−·06	H_2.
32·14	307·5	307·0	+0·5	0·85	·84	+·01	Σ.
35·92	315·4	313·7	+1·7	1·08	·93	+·15	Sm.
36·98	318·8	315·8	+3·0	0 94	0·96	−·02	Σ.
39·77	318·2	320·4	−2·2	1·08	1·04	+·04	Sm.
39·79	319·2	0·4	−1·2	1·14	·04	+·10	Da.
40·35	321·2	1·3	−0·1	1·05	·05	·00	Md.
40·98	320·7	2·1	−1·4	1·13	·07	+·06	Da.
41·59	323·5	2·8	+0·7	1·17	·08	+·09	Md.
41·64	322·2	323·1	−0·9	1·15	1·09	+·06	OΣ.
41·87	322·6	323·4	−0·8	1·13	1·10	+·03	Da.
42·34	323·6	3·8	−0·2	0·99	1·11	−·12	Ka.
42·77	324·5	4·3	+0·2	1·03	1·12	−·09	Md.
42·94	324·2	4·5	−0·3	1·06	1·12	−·06	Da.
43·12	322·6	4·8	−2·2	0·98	1·14	−·16	Sm.
43·92	324·8	5·8	−1·0	1·17	1·18	−·01	Da.
46·78	329·0	9 0	0·0	1·21	1·19	+·02	OΣ.
46·93	330·2	9·2	+1·0	1·17	1·19	−·02	Da.
46·99	327·8	9·3	−1·5	1·24	1·20	+·04	Md.
47·68	330·4	330·1	+0·3	1·05	1·20	−·15	Mit.
47·89	328·3	0·2	−1·9	1·21	1·21	·00	Md.
47·92	331·1	0·3	+0·8	1·28	1·23	−·05	Da.
50·91	333·3	3·4	−0·1	1·22	1·23	−·01	Da.
51·00	332·2	3·6	−1·4	1·37	1·24	+·13	Md.
51·78	335·1	4·3	+0·8	1·29	1·24	+·05	Md.
51·94	336·6	4·5	+2·1	1·11	1·24	−·13	Flt.
52·60	334·3	5·1	−0·8	1·33	1·25	+·08	Md.
52·69	333·8	5·2	−1·4	1·32	1·25	+·07	OΣ.
52·83	335·4	5·3	+0·1	1·28	1·25	+·03	Sm.
53·09	335·8	5·6	+0·2	1·41	1·26	+·15	Md.
53·89	336·4	6·5	−0·1	1·21	1·26	−·05	Da.
53·96	338·1	6·6	+1·5	1·18	1·27	−·09	J.
54·69	338·3	7·3	+1·0	1·24	1·28	−·04	OΣ.
54·75	337·1	7·4	−0·3	1·28	1·28	·00	Da.
54·91	340·2	7·5	+2·7	1·25	1·28	−·03	Mor.
55·29	335·3	7·7	−2·2	1·35	1·28	+·07	Md.
55·52	335·8	7·9	−2·1	1·30	1·28	+·02	De.

Epoch.	O	C	O−C	O	C	O−C	Observer.
	°	°	°	″	″	″	
1855·99	336·1	338·4	−2·3	1·18	1·28	−·10	De.
56·09*	344·3	8·5	+5·8	1·30	1·28	+·02	Win.
56·61	338·0	9·1	−1·1	1·25	1·29	−·04	De.
56·73	338·5	9·2	−0·7	1·32	1·29	+·03	O⊼.
56·97	338·9	9·3	−0·4	1·25	1·29	−·04	De.
57·03	339·2	339·4	−0·2	1·29	1·29	·00	Sec.
57·75	339·1	340·0	−0·9	1·37	1·30	+·07	Md.
57·84	338 3	0·1	−1·8	1·17	1·30	−·13	Sec.
58·04	338·8	0·3	−1·5	1·32	1·31	+·01	Md.
59·36	343·3	1·6	+1·7	1·23	1·32	−·09	Md.
59·83	341·5	2·0	−0·5	1·24	1·32	−·08	Da.
59·89	340 2	2·1	−1·9	1·34	1·33	+·01	Md.
60·83	343·9	2·8	+1·1	1·42	1·33	+·09	Md.
61·74	344·2	3·6	+0·6	1·30	1·34	−·04	O⊼.
61·81	342·3	3·7	−1·4	1·34	1·34	·00	Md.
62·78	344·8	4·3	+0·5	1·17	1·35	−·18	De.
62·83	344·5	4·4	+0·1	1·31	1·35	−·04	Md.
63·83	345·2	5·5	−0·3	1·22	1·35	−·13	De.
64·77	345·8	6·4	−0·6	1·27	1·36	−·09	De.
65·11	348·9	6·6	+2·3	1·57	1·36	+·21	Eng.
65·65	346·6	7·0	−0·4	1·26	1·36	−·10	De.
65·69	344·9	7·1	−2·2	1·35	1·36	−·01	Knott.
65·73	348·6	7·2	+1·4	1·10	1·36	−·26	Ta.
66 05	349·3	7·4	+1·9	1·41	1·36	+·05	Sec.
66·74	349·8	7·9	+1·9	1·46	1·37	+·09	Har.
66·81	347·8	8·0	−0·2	1·17	1·37	−·20	De.
66·83	345·8	8·0	−2·2	1·41	1·37	+·04	Ta.
67·03	351·0	8·2	+2·8	1·25	1·37	−·12	Ka.
67·70	348·5	8·7	−0·2	1·29	1·37	−·08	De.
68·41	349·4	9·3	+0·1	1·17	1·37	−·20	Har.
68·66	350·7	9·5	+1·2	1·44	1·37	+·07	De.
68·76	350·8	349·6	+1·2	1·57	1·37	+·20	Br.
69·66	350·3	350·6	−0·3	1·36	1·38	−·02	De.
69·72	351·1	0·6	+0·5	...	...	...	Ta.
69·86	349·1	0·8	−1·7	1·35	1·38	−·03	Har.
70·14	350·6	0·9	−0·3	1·25	1·38	−·13	Gld.
70·35	350·5	1·0	−0·5	1·27	1·38	−·11	De.
70·60	350·9	1·2	−0·3	1·35	1·38	−·03	Gld.

* A single observation, apparently 5° in error.

Epoch.	O	C	O−C	O	C	O−C	Observer.
	°	°	°	″	″	″	
1871·60	353·5	352·0	+1·5	1·25	1·38	−·13	Gld.
71·62	353·2	2·0	+1·2	1·47	1·38	+·09	De.
72·03	351·9	2·4	−0·5	1·40	1·39	+·01	W. & S.
72·65	353·3	2·8	+0·5	1·40	1·39	+·01	De.
72·86	349·0	3·0	−4·0	1·27	1·39	−·12	Ta.
72·88	354·1	3·0	+1·1	1·22	1·39	−·17	W. & S.
73·68	353·1	3·8	−0·7	1·41	1·39	+·02	De.
73·81	352·7	3·9	−1·2	1·38	1·39	−·01	W. & S.
73·86	353·2	4·0	−0·8	1·32	1·39	−·07	Ta.
73·91	353·6	4·0	−0·4	1·45	1·39	+·06	Gld.
74·04	355·8	4·1	+1·7	1· ±	1·39	...	Nobile.
74·80	355·2	4·7	+0·5	1·32	1·38	−·06	De.
74·94	355·5	4·8	+0·7	1·45	1·38	+·07	W. & S.
75·54	355·9	5·3	+0·6	1·42	1·38	+·04	W. & S.
75·62	356·5	5·4	+1·1	1·30	1·38	−·08	De.
75·70	356·2	5·5	+0·7	1·42	1·38	+·04	Du.
76·00	358·1	5·8	+2·3	1·34	1·38	−·04	Hall.
76·07	355·4	5·8	−0·4	...	...	...	Gld.
76·08	359·0	5·8	+3·2	...	...	...	Dob.
76·75	354·7	6·4	−1·7	1·16	1·37	−·21	Dob.
76·78	356·7	6·4	+0·3	1·43	1·37	+·06	De.
76·95	358·1	6·5	+1·6	1·32	1·37	−·05	W. & S.
77·02	355·9	6·6	−0·7	1·28	1·37	−·09	Sp.
77·02	355·6	6·6	−1·0	1·28	1·37	−·09	Sch.
77·19	358·2	6·8	+1·4	1·49	1·37	+·12	Pl.
77·52	357·1	7·0	+0·1	1·37	1·37	·00	De.
77·62	356·0	7·0	−1·0	...	1·37	...	Gld.
77·94	358·3	7·4	+0·9	1·37	1·37	·00	W. & S.
78·45	357·8	7·7	+0·1	...	1·36	...	Gld.
78·87	356·4	8·2	−1·6	1·33	1·36	−·03	Hall.
78·90	357·6	8·2	−0·6	1·20	1·36	−·16	Dob.
79·86	360·5	8·8	+1·7	...	1·36	...	Dob.
80·11	359·5	9·1	+0·4	1·38	1·36	+·02	Jed.
80·89	359·8	359·6	+0·2	1·32	1·35	−·03	Dob.
82·01	360·9	360·6	+0·3	1·34	1·34	·00	Schi.
82·10	360·6	0·7	−0·1	1·36	1·34	+·02	Eng.
82·81	361·8	1·5	+0·3	1·32	1·33	−·01	Dob.
83·02	361·2	1·6	−0·4	1·37	1·33	+·04	Eng.
83·16	363·1	1·7	+1·4	1·51	1·33	+·18	Seab.

Epoch.	O	C	O−C	O	C	O−C	Observer.
1883·32	361°·2	361°·8	−0°·6	1″·41	1″·33	+″·08	Eng.
83·86	361·7	1·8	−0·1	1·27	1·32	−·05	Per.
84·12	361·9	2·1	−0·2	1·27	1·31	−·04	Eng.
85·25	364·1	3·1	+1·0	1·35	1·30	+·05	Schi.
85·28	362·0	3·1	−1·1	1·15	1·30	−·15	Per.
87·01	365·2	5·1	+0·1	1·15	1·28	−·13	Schi.
88·05	367·4	6·1	−1·3	1·18	1·27	−·09	Schi.
88·51	366·1	6·6	−0·5	1·21	1·26	−·05	Lev.
1891·08	369·2	368·8	+0·4	1·35	1·25	+·10	Maw.*

Proper Motions of Twenty Southern Stars.

By J. L. E. Dreyer, Ph.D.

In the *Monthly Notices* for May 1886 I discussed the Proper Motions of twenty-nine telescopic stars occurring in the Second Armagh Catalogue of Stars. In the present paper I have put together the positions from all available sources of twenty stars which seem endowed with proper motion, which (with two exceptions) has not been noticed before, at least so far as I am aware.

These stars are all situated in the region covered by the southern *Durchmusterung*, viz. between 2° and 23° south declination. In 1881 the late Professor Schönfeld suggested to me to observe about nine hundred stars, of which the earlier observations differed considerably *inter se* or from the Bonn zones. These stars were accordingly observed with the Dunsink Meridian Circle by myself, and afterwards by Mr. Rambaut, and the resulting places for 1885 were published in part vi. of the *Dunsink Observations*. I have recently examined the more remarkable cases which might arise from proper motion, but only in twenty cases could such be established with certainty, while a number of other cases must be deferred until further observations have been obtained. I have also passed over a number of stars the proper motions of which have been determined elsewhere.

As the materials were rather scanty, and will ere long be considerably improved by the publication of the Paris Catalogue and the southern zone-work of the Astronomische Gesellschaft, I have not applied any of the so-called systematic corrections to

* The last measure, a mean of three nights, was kindly made for me by Mr. W. H. Maw, for comparison after the orbit was computed. The angle agrees well with that computed.

the various catalogues. All the places were reduced to 1875 with Struve's constant, and where there were more than three different epochs the proper motion was deduced by the method of least squares. Lalande's and Bessel's observations were reduced anew with Von Asten's and Luther's tables. The new editions of Argelander's (Oeltzen's) and Lamont's catalogues were used.

S.D. −12°, 20; Magn. 8·3.

		h m s	° ′ ″
Bessel	1823·8	0 7 37·18	−11 59 50·8 (1 obs.)
Greenwich 6-Year	1852·9	37·72	57·3 (1)
„ 7-Year	1854·9	37·73	57·1 (3)
Santini	1857	37·90	56·1 (2)
Yarnall	1862·0 and 60·5	37·88	57·9 (2, 3)
Schjellerup	1863·0	37·89	59·4 (1)
Königsberg (*A.N.* 1804)	1869·9	38·27	63·0 (2)
Dunsink	1882·5	38·65	62·7 (3)

Giving Bessel, Six-Year Cat., Schjellerup and Königsberg half-weight, the P.M. is found = + 0ˢ·0218 and −0″·172, with which these places become:

	h m s	° ′ ″
Bessel	0 7 38·30	−11 59 59″6
6-Year	38·20	61·1
7-Year	38·17	60·6
Santini	38·29	59·2
Yarnall	38·16	60·4
Schjellerup	38·15	61·5
Königsberg	38·38	63·9
Dunsink	38·49	61·4

S.D. −7°, 603; Magn. 8·2.

		h m s	° ′ ″
Lalande	1796·7	3 22 7·15	−6 57 18″4 (1)
Bessel	1824·9	8·30	25·7 (1)
Paris	1860·5 and 1862·0	9·03	31·4 (2, 1)
Dunsink	1882·0	9·73	36·2 (2)

The P.M. in R.A. has been remarked by M. Bossert, but the new reduction of Bessel's observation clearly shows that there is also motion in declination. With P.M. = + 0ˢ·0299 and −0″·206 the observed places become:

		h m s	° ′ ″
Lalande		3 22 9·49	−6 57 34·5
Bessel		9·80	36·0
Paris		9·46	34·1
Dunsink		9·52	34·8

S.D. −10°, 2857; Magn. 7·6.

		h m s	° ′ ″	
Lalande	1798·2	9 26 24·48	−10 38 9·4	(1)
Munich	1845·3	23·87	7·5	(1)
Brussels	1869·8 and 1867·0	23·49	5·2	(5,4)
Dunsink	1883·2	23·03	6·2	(4)

Giving the two first places half-weight, we find P.M. = − 0ˢ·0171 and + 0″·032, which gives:

	h m s	° ′ ″
Lalande	9 26 23·17	−10 38 7″0
Munich	23·36	6·6
Brussels	23·40	5·0
Dunsink	23·17	6·5

S.D. −10°, 2998; Magn. 8o.

		h m s	° ′ ″	
Bessel	1824·2	10 2 20·18	−10 30 26″4	(2)
Santini	1857	19·68	20·0	(2)
Munich	1865·3	19·48	19·5	(1)
Gould	1878·2	19·30	20·6	(5)
Dunsink	1883·2	19·20	21·0	(4)

There does not seem to be any motion in declination. Adopting P.M. = − 0ˢ·0172, the observed Right Ascensions become:

	h m s
Bessel	10 2 19·31
Santini	19·37
Munich	19·31
Gould	19·36
Dunsink	19·34

S.D. −5°, 3071; Magn. 8·0.

		h m s	° ′ ″	
Bessel	1824·2	10 21 60·14	−5 56 59″2	(1)
Munich	1862·3	58·90	57 9·0	(4)
Schjellerup	1863·3	58·72	9·9	(1)
Dunsink	1883·2	58·41	15·1	(4)

Giving Bessel and Schjellerup half-weight, P.M. = − 0ˢ·0296 and − 0″·264, with which the observed places become:

		h	m	s	°	′	″	
Bessel		10	21	58·64	−5	57	12·6	
Munich				58·52			12·4	
Schjellerup				58·37			13·0	
Dunsink				58·65			12·9	
S.D. −17°, 3488; Magn. 8·2.								
Lalande	1796·3	11	45	19·51	−17	28	18·7	(1)
Bonn	1853·2			19·57			34·2	(1)
Bonn	1864·3			19·63			35·9	(1)
Dunsink	1882·9			19·76			38·7	(3)

The P.M. in R.A. is somewhat uncertain, and in declination it is just possible that Lalande is merely 15″ in error. However a P.M. = + 0ˢ·0028 and − 0″·231 agrees thus with the observed places:

		h	m	s	°	′	″	
Lalande		11	45	19·73	−17	28	36·9	
Bonn				19·63			39·2	
Bonn				19·66			38·4	
Dunsink				19·74			36·9	
S.D. −5°, 3444; Magn. 8·0.								
Lalande	1795·3	12	4	57·17	− 5	13	28·9	(1)
Bessel	1823·3			56·39			28·7	(2)
Munich	1850·8			56·00			34·2	(2)
Bonn	1855·3			55·90			33·2	(2)
Dunsink	1882·7			55·24			37·7	(2)

Giving Lalande half-weight, the P.M. is found = − 0ˢ·0214 and − 0″·112, which gives:

		h	m	s	°	′	″	
Lalande		12	4	55·46	− 5	13	37·8	
Bessel				55·28			34·5	
Munich				55·48			36·9	
Bonn				55·58			35·4	
Dunsink				55·40			36·8	
S.D. −10°, 3457; Magn. 8·6.								
Lalande	1798·2	12	16	5·87	−10	51	52·0	(1)
Munich	1868·4			6·99			54·2	(2)
Dunsink	1883·0			7·17			58·9	(3)

Assuming P.M. = + 0ˢ·015 and − 0″·10, these places become:

	h	m	s	°	′	″
Lalande	12	16	7·02	−10	51	59·7
Munich			7·09			54·9
Dunsink			7·05			58·1

S.D. −7°, 3409; Magn. 6·3.

		h	m	s	°	′	″	
Lalande	1795·3	12	21	31·62	− 7	58	53·4	(1)
Bessel	1824·3			31·78		59	2·9	(1)
Brisbane	...			...			1·1	(1)
Taylor	1835			31·35			2·9	(2)
Santini	1843			31·09			7·1	
Cape 1850	1852·4			31·00			3·1	(1)
Brussels	1866·8, 1867·5			30·71			5·0	(4, 5)
Armagh	1873·1			30·65			6·8	(5)
Greenwich 9-Year,	1876·4			30·53			4·0	(3)
Gould	1877·5			30·52			5·3	(4)
Dunsink	1882·3			30·50			5·4	(2)

Probably Lalande should be corrected by − 10″, and there is scarcely any indication of P.M. in declination. Giving the five last places double weight, we find the P.M. in R.A. = − 0ˢ·0174, which makes the observed places agree as follows:—

	h	m	s
Lalande	12	21	30·23
Bessel			30·90
Taylor			30·65
Santini			30·53
Cape 1850			30·61
Brussels			30·57
Armagh			30·62
Greenwich			30·55
Gould			30·56
Dunsink			30·63

S.D. −2°, 3528; Magn. 8·5.

		h	m	s	°	′	″	
Lalande	1795·3	12	23	22·22	−2	36	32·2	(1)
Munich	1843·9			20·79			56·0	(2)
Dunsink	1882·8			20·76		37	24·1	(2)

Lalande only observed the transit over one wire, and does not give any fraction of the observed second. In declination there seems to be P.M. equal to about $-0''.66$, which gives:

Lalande ...	...	...	...	-2°	$37'$	$26''.8$
Munich ...	...	...	...			$16''.5$
Dunsink ...	...	...	...			$19''.0$

If Lalande should be $10''$ in error, a larger P.M. would make the agreement much better.

S.D. $-8°$, 4352; Magn. 8·8.

		h	m	s				
Bessel	1823·4	16	48	51·85	-8°	$5'$	$25''.0$	(1)
Dunsink	1886·2			47·86		6	20·2	(1)

Unless there is some error in Bessel's position, this is a very remarkable case of P.M., $= -0^s.063$ and $-0''.88$, or $1''.3$ along a great circle.

S.D. $-22°$, 4475; Magn. 8·5.

		h	m	s				
Lalande	1795·5	17	51	26·85	-22°	$21'$	$41''.1$	(1)
Argelander	1850·0			26·14			49·4	(2)
Dunsink	1885·5			25·38			56·6	(1)

Adopting a P.M. $= -0^s.019$ and $-0''.16$, these places become:

	h	m	s			
Lalande	17	51	25·34	-22°	$21'$	$53''.8$
Argelander			25·66			53·4
Dunsink			25·58			54·9

S.D. $-6°$, 4817; Magn. 8·6.

		h	m	s				
Lalande	1796·5	18	31	16·86	-6°	$53'$	$11''.8$	(1)
Bessel	1824·5			16·21			31·8	(1)
Munich	1867·2			16·00			44·1	(2)
Dunsink	1886·1			15·83			52·1	(2)

Giving the last two places double weight, the P.M. is found $= -0^s.0098$ and $-0''.420$, which gives:

	h	m	s			
Lalande	18	31	16·09	-6°	$53'$	$44''.8$
Bessel			15·72			53·0
Munich			15·92			47·4
Dunsink			15·94			47·5

S.D. −4°, 4617; Magn. 9·0.

		h m s	° ′ ″	
Lalande	1794·6	18 47 47·24	− 4 43 56·8	(1)
Bessel	1824·5	47·17	44 21·7	(1)
Munich	1857·0	47·02	31·7	(3)
Dunsink	1886·6	46·68	47·6	(1)

Giving the Munich place double weight, the P.M. is found = − 0ˢ·0063 and − 0″·521, which gives:

	h m s	° ′ ″
Lalande	18 47 46·73	− 4 44 38·7
Bessel	46·85	48·0
Munich	46·91	41·1
Dunsink	46·75	41·6

S.D. −6°, 5360, Magn. 8·5.

		h m s	° ′ ″	
Lalande	1794·5	19 58 39·22	− 6 56 8·9	(1)
Taylor	1835	39·25	15·6	(2, 3)
Munich	1854·0	39·14	18·2	(4)
Schjellerup	1862·6	38·85	17·2	(1)
Gould	1880·7	38·76	19·0	(3)
Dunsink	1884·6, 85·6	38·76	18·2	(1, 1)

Giving Munich and Gould double weight the P.M. is found = − 0ˢ·0076 and − 0″·094, which, applied to the observations, gives:

	h m s	° ′ ″
Lalande	19 58 38·61	− 6 56 16·5
Taylor	38·87	19·4
Munich	38·98	20·2
Schjellerup	38·76	18·4
Gould	38·80	18·5
Dunsink	38·83	17·2

S.D. −8°, 5318, Magn. 8·7.

		h m s	° ′ ″	
Lalande	1794·6	20 13 1·01	− 8 49 52·0	(1)
Munich	1846·6	1·04	50 12·5	(1)
Dunsink	1881·7	1·01	16·3	(2)

In Right Ascension there is evidently not any P.M., and in Declination the agreement cannot be made very good. P.M. = − 0″·23 gives:

	° ′ ″
Lalande	−8 50 10·5
Munich	19·0
Dunsink	13·8

S.D. – 21°, 6035, Magn. 8·4.

		h m s	° ′ ″	
Lalande	1795·6	21 25 23·56	−21 30 6·9	(1)
Munich	1847·8	22·63	6·8	(1)
Argelander	1849·6	22·50	9·0	(1)
Dunsink	1884·2	21·91	15·4	(2)
Cincinnati	1885·7	21·85	11·5	(4)

The last two places were given double weight. P.M. = − 0ˢ·0196 and − 0″·078 gives:

	h m s	° ′ ″
Lalande	21 25 22·00	−21 30 13″1
Munich	22·10	8·9
Argelander	22·00	11·0
Dunsink	22·09	14·7
Cincinnati...	22·06	10·7

S.D. – 16°, 6046, Magn. 6·5.

		h m s	° ′ ″	
Lalande	1795·7	22 7 51·80	−16 25 0″0	(2)
Argelander	1849·6	51·70	17·8	(1)
Rümker (Kam.)	1855?	52·07	26·0	(1)
Gould	1877·8	51·98	32·0	(4)
Dunsink	1881·8	52·17	37·5	(1)

These places give a P.M. = + 0ˢ·0028 and − 0″·414, which, applied to the observations, gives:

	h m s	° ′ ″
Lalande	22 7 52·02	−16 25 32″8
Argelander	51·77	28·3
Rümker	52·13	34·3
Gould	51·97	30·8
Dunsink	52·15	34·7

S.D. – 18°, 6140, Magn. 7·8.

		h m s	° ′ ″	
Lalande	1795·7	22 26 19·27	−18 8 27″5	(2)
Piazzi	1800 ±	19·07	30·5	(3)
Taylor	1835	19·05	31·9	(3, 3)
Argelander	1849·8	18·32	30·2	(2)
Gould	1879·7	18·09	33·8	(3)
Dunsink	1882·4	18·19	35·6	(3)

The Proper Motion is = − 0ˢ·0133 and − 0″·065, which gives:

	h	m	s	°	′	″
Lalande	22	26	18·22	−18	8	32·7
Piazzi			18·07			35·4
Taylor			18·52			34·5
Argelander			17·98			31·8
Gould			18·15			33·5
Dunsink			18·29			35·1

S.D. − 10°, 6008, Magn. 6·8.

		h	m	s	°	′	″	
Lalande	1798·3	22	46	9·69	−10	43	20·6	(2)
Bessel	1823·7			10·43			25·4	(1)
Santini	1843			10·28			20·9	(1)
Munich	1845·4			10·56			20·1	(2)
Geneva	1847·6			10·50			23·1	(5)
Rümker	1849·8			10·50			20·9	(1)
Santini	1857·0			10·46			19·7	(3)
Berlin (Kam.)	1862·7			10·89			20·6	(1)
Armagh	1873·7			10·81			19·9	(2)
Gould	1878·8			10·99			21·6	(4)
Dunsink	1882·7			11·02			20·1	(3)

The late Professor C. H. F. Peters pointed out in the *Astr. Nachr.*, No. 2247, that this star had probably P.M. in Right Ascension. The above more complete collection of positions shows that this is indeed the case, the amount being + 0ˢ·0159, which gives:

	h	m	s
Lalande	22	46	10·91
Bessel			11·25
Santini			10·79
Munich			11·03
Geneva			10·94
Rümker			10·90
Santini			10·75
Berlin			11·09
Armagh			11·02
Gould			10·93
Dunsink			10·90

On the Orbit of the Periodic Comet 1867 I.

By Ludwig Becker, Ph.D.

(*Communicated by Professor R. Copeland*).

I.

This faint comet was discovered by M. Stephan at Marseilles on January 22, 1867, and a week later independently by W. Tempel. At first it appeared like a pretty bright round nebula with a well-defined nucleus, which by its eccentric position suggested the existence of a fan-shaped tail. Its intensity increased a little up to the first week of February, at which time the nucleus was elongated and the nebulous mass surrounding it was about 1′·5 in diameter, but somewhat extended in position-angle 75°. By the end of February the diameter had increased to 2′, and the intensity of the nucleus had gone down to that of a star of the 12th magnitude. The comet was last observed on April 4, when the 15-inch refractor of the Harvard College Observatory showed it as a very faint object.

There are 63 observations, which, extending over 69 days, cover a heliocentric arc of 41°·6, viz. from $v=3°·3$ to 44°·9. 39 of them belong to the first 17 days. I am much indebted to M. Stephan for having forwarded a fine series of observations hitherto unpublished, which have extended the time of observation by 10 days.

At the time of the comet's visibility parabolic elements were published in the *Astronomische Nachrichten* by Messrs. Valentiner, Oppolzer, and Vogel, while Mr. Searle derived elliptic elements with a period of 33·62 years from three observations which embrace almost the whole heliocentric arc.

II.

Although Mr. Searle's elements represent the observations very well, I preferred to base these computations on elements which I had computed some years ago at the suggestion of my esteemed teacher, the late Professor Schönfeld, of Bonn, from all the observations, except those made at Marseilles. This was before the comparison stars had been redetermined. These elements are—

ELEMENTS I.

T = 1867, January, 20·51309, Berlin M.T.

$\omega = 357° 42' 49''·9$
$\Omega = 78\ 19\ 40·6$ } Mean Equinox 1867·0.
$i = 18\ 12\ 59·8$

$\log q = 0·1991244.$

$\log e = 9·9451467.$

Period = 48·7 years.

They give the following ephemeris for Berlin Midnight, the places being corrected for precession and nutation, but not for aberration :—

Berlin, Midnight. 1867.	R.A. h m s	Decl. ° ′ ″	Log Δ.
Jan. 24	2 32 4·59	+15 9 13·8	0·0574
25	34 8·60	15 37 28·5	·0600
26	36 14·43	16 5 31·7	·0625
27	38 22·06	16 33 23·0	·0651
28	40 31·46	17 1 1·8	·0678
29	42 42·64	17 28 27·7	·0704
30	44 55 59	17 55 40·3	·0731
31	47 10·28	18 22 39·1	·0758
Feb. 1	49 26·69	18 49 23·8	·0785
2	51 44·80	19 15 53·9	·0812
3	54 4·61	19 42 9·0	·0839
4	56 26·10	20 8 8·8	·0867
5	2 58 49·23	20 33 52·8	·0895
6	3 1 14·00	20 59 20·7	·0923
7	3 40·38	21 24 32·0	·0951
8	6 8·35	21 49 26·5	·0980
9	8 37·87	22 14 3·7	·1008
10	11 8·93	22 38 23·3	·1037
11	3 13 41·52	+23 2 25·0	0·1066
Feb. 18	3 32 9·79	+25 41 47·3	0·1272
19	34 53·55	26 3 14·1	·1302
20	37 38·58	26 24 20·3	·1332
21	40 24·87	26 45 5·7	·1362
22	43 12·41	27 5 30·0	·1392
23	46 1·15	27 25 32·9	·1422
24	48 51·08	27 45 14·4	·1453
25	51 42·16	28 4 34·1	·1484
26	54 34·37	28 23 32·0	·1514
27	3 57 27·69	28 42 7·9	·1545
28	4 0 22·10	29 0 21·5	·1576
Mar. 1	3 17·56	29 18 12·9	·1607
2	6 14·04	29 35 41·9	·1638
3	9 11·51	29 52 48·2	·1669
4	12 9·95	30 9 31·9	·1700
5	15 9·33	30 25 52·9	·1732

Berlin, Midnight. 1867.	R.A. h m s	Decl. ° ′ ″	Log Δ.
Mar. 6	4 18 9·59	+30 41 51·1	0·1763
7	21 10·72	30 57 26·3	·1794
8	24 12·67	31 12 38·5	·1826
9	4 27 15·42	+31 27 27·7	0·1857
Mar. 25	5 17 15·17	+34 32 16·1	0·2364
26	20 25·47	34 40 34·9	·2396
27	23 35·89	34 48 31·4	·2427
28	26 46·40	34 56 5·9	·2459
29	29 56·95	35 3 18·4	·2491
30	33 7·52	35 10 9·1	·2522
31	36 18·07	35 16 38·0	·2554
Apr. 1	39 28·58	35 22 45·5	·2585
2	42 39·00	35 28 31·7	·2617
3	45 49·30	35 33 56·8	·2648
4	5 48 59·43	+35 39 1·2	0·2680

III.

The comparison stars were reduced from the catalogues to 1867·0 by employing Struve's constants of precession. Those observed by Lalande and Bessel were derived from the original zone-observations. All the positions refer to the system of the *Fundamental-Catalog der Astronomischen Gesellschaft.* For the Second Armagh, the Glasgow, Greenwich 7-year, 1864, and Yarnall catalogues I employed the published reduction tables. The meridian observations, which are based on *Der vorläufige Catalog der Astronomischen Gesellschaft*, are corrected by the table given on pp. 10, 11 in *Publication XIV der Astr. Gesellschaft*, under the heading "Pulkowa, 1845." For reducing the positions of the new Paris catalogues to the system of the *A.G.C.*, 62 stars of the third Paris catalogue were compared with the Glasgow catalogue and a table prepared for the path of the comet only. This table was then combined with the reduction table belonging to the Glasgow catalogue. The positions of the second Paris catalogue were first brought to the system of the third. The table employed had been obtained from 350 comparisons of the positions of telescopic stars which lie near the apparent path of the comet. The same method was applied to Paris I. In order to utilise the reduction tables published by Argelander, I reduced all the positions of the stars, which occur in the *Tabulæ Reductionum*, from the *A.G.C.* to the epoch 1860·0. In so doing *α Geminorum*, *α Canis minoris*, and *α Canis majoris* were excluded. Treating the differences between

the two catalogues in the manner introduced by Professor Auwers, I find the following tables:—

A.G.C.—Tab. Red., 1860.

Decl.	$\Delta\alpha_\delta$.	$\Delta\delta_\delta$.	R.A.	$\Delta\alpha_\alpha$.	$\Delta\delta_\alpha$.
°	s	"	h	s	"
−30	+0·025	−1·25	0	+0·006	−0·07
−25	+0·014	−1·14	1	+0·003	+0·02
−20	+0·004	−1·03	2	−0·004	+0·10
−15	−0·005	−0·92	3	−0·013	+0·17
−10	−0·010	−0·81	4	−0·018	+0·22
− 5	−0·014	−0·70	5	−0·020	+0·25
0	−0·016	−0·62	6	−0·021	+0·26
+ 5	−0·017	−0·59	7	−0·018	+0·24
+10	−0·018	−0·63	8	−0·013	+0·19
+15	−0·018	−0·74	9	−0·007	+0·11
+20	−0·017	−0·78	10	−0·002	+0·02
+25	−0·016	−0·74	11	+0·001	−0·07
+30	−0·013	−0·68	12	+0·003	−0·17
+35	−0·009	−0·58	13	+0·004	−0·24
+40	−0·005	−0·44	14	+0·004	−0·30
+45	0·000	−0·26	15	+0·005	−0·34
+50	+0·006	−0·03	16	+0·005	−0·37
+55	+0·013	+0·25	17	+0·006	−0·38
+60	+0·020	+0·58	18	+0·006	−0·38
+65	+0·029	+0·97	19	+0·007	−0·37
+70	+0·039	+1·40	20	+0·007	−0·33
+75	+0·048	+1·82	21	+0·008	−0·28
			22	+0·009	−0·22
			23	+0·008	−0·15

The sums of the residuals left by these values in the differences of the two catalogues with regard to the signs are $-0^s{\cdot}103$ and $-0''{\cdot}09$ respectively. The average errors amount to $0^s{\cdot}022$ and $0''{\cdot}23$. Three residuals in R.A. are larger than $0^s{\cdot}05$ (belonging to declinations greater than 50°), and six in Decl. exceed $0''{\cdot}5$. The maximum residuals are $0^s{\cdot}085$ and $0''{\cdot}75$ respectively.

All the comparison stars I have reobserved with the 8·6-inch Transit-Circle of Lord Crawford's observatory at Dun Echt.

In taking the mean values of the several determinations of the stars, all the Transit-Circle positions received equal weights, unless they rested on a single observation. The same weight was, however, given to the Leyden zone-stars, even though but

once observed. The positions derived from the *Histoire céleste* were excluded, as were also the declinations of three Bessel zone-stars, Nos. 40, 41, 45. All the other Bessel zone-stars received half-weight. For stars Nos. 4 and 34 the more recent observations alone were taken into account, in order to bring the epoch of the mean position as near as possible to 1867.

List of Comparison Stars.

Mean Equinox, 1867·0.

No.	Mg.	R.A. h m s	Decl. ° ′ ″	
1	8·8	2 36 27·84	+15 32 22·4	AN 2007, 2047, DE.
2	7·8	2 38 19·57	+16 27 27·3	[HC] Par II, III, AN 2047, 2090, DE.
3	12	2 40 10·51	+17 26 6·7	DE.
4	5·7	2 41 52·48	+16 54 32·8	Br, HC, Pi, PM, Arm I, R I, II, Par I, II, III, RC I, II, Y, Gl, DE.
5	9·5	2 45 17·28	+17 48 14·0	DE.
6	9·4	2 47 50·95	+18 19 53·4	DE.
7	9·3	2 49 53·17	+18 41 8·9	R, Par III, DE.
8	9·0	2 51 53·91	+19 32 0·2	DE.
9	12	2 52 9·61	+19 8 22·9	DE.
10	9·1	2 55 7·23	+20 25 37·2	BZ, AN 1768, 1794, DE.
11	8·3	2 55 34·98	+19 48 39·6	AN 1794, Kü, DE.
12	8·8	2 56 14·77	+19 35 21·7	R, AN 1768, DE.
13	7·7	2 56 37·57	+20 57 2·3	[HC] BZ, Par II, III, Arm II, DE.
14	7·5	2 57 53·67	+20 23 0·0	[HC] BZ, R II, AN 1637, 1765, Par III, DE.
15	8·5	2 59 2·11	+20 7 25·4	PM, AN 1765, 1768, DE.
16	12	2 59 24·01	+20 30 50·4	DE.
17	7·7	3 2 27·00	+21 14 16·8	[HC] BZ, Par II, III, AN 1925, Arm, DE.
18	7·8	3 2 36·01	+20 45 47·7	BZ, DE.
19	7·7	3 3 0·32	+21 23 15·8	[HC] BZ, Par I, II, R II, DE.
20	8·8	3 5 5·42	+21 24 38·8	DE.
21	8·0	3 6 8·66	+21 45 12·1	BZ, DE.
22	9·5	3 6 42·15	+22 12 57·0	DE.
23	8·3	3 8 31·47	+22 16 2·9	AN 1632, DE.
24	7·3	3 9 12·19	+22 38 10·7	[HC] BZ, Par I, II, III, DE.
25	9·0	3 12 16·21	+22 57 21·9	BZ, DE.
26	7·4	3 35 46·09	+25 57 21·3	[HC] Par II, AN 1765, 1925, DE.
27	9·0	3 42 43·35	+26 40 14·6	BZ, Y, DE.
28	8·6	3 44 51·34	+27 7 24·3	DE.

No.	Mg.	R.A. h m s	Decl. ° ′ ″	
29	8·5	3 45 11·73	+27 37 58·6	BZ, DE.
30	6·7	3 53 14·40	+28 7 31·7	BZ, R II, DE.
31	7·5	3 54 4 86	+27 45 4·0	[HC] BZ, PM, Par II, DE.
32	8·3	3 54 47·65	+28 4 58·0	BZ, DE.
33	7·8	3 55 26·84	+28 17 25·7	[HC] R II, DE.
34	5·4	3 58 47·39	+28 38 19·9	Br, HC, Pi, R, Arm, Par I, II, Y, 7yrC, DE.
35	7·0	4 6 50·07	+29 34 8·9	BZ, Par II, DE.
36	9·2	4 10 46·03	+30 8 0·6	[AN 1663], DE.
37	8·9	4 22 55·78	+30 59 16·9	BZ, LnZ, DE.
38	8·2	4 24 12·74	+31 7 1·9	[HC] BZ, Par II, DE.
39	9·5	5 20 33·56	+34 41 33·1	AN 1639, DE.
40	8·6	5 26 43·16	+34 57 58·3	BZ, DE.
41	7·9	5 30 0·03	+34 59 43·9	BZ, LnZ, DE.
42	8·9	5 33 45·84	+35 6 58·5	BZ, DE.
43	8·5	5 33 57·02	+35 18 36·2	[HC] DE.
44	12	5 42 48·37	+35 29 51·7	DE.
45	7·3	5 47 59·43	+35 33 19·4	BZ, DE.

It may be mentioned that in addition to the abbreviations in general use Kü designates Küstner's Catalogue of 670 stars, LnZ Leiden Zone-stars, and DE my own Dun Echt observations.

IV.

The observations of the comet are published in *Astr. Nachr.*, Nos. 1627, 1630, 1631, 1632, 1639, 1663, 1764, 1768, in the Annals of Harvard College Observatory and in those of the Vienna Observatory. The reductions to the apparent places and the parallaxes have been computed afresh. For the Berlin observation of February 9 a wrong comparison star has been given, the one used being No. 23 of the preceding list. The unpublished observations already mentioned as having been communicated by M. Stephan are as follows:—

Instr.: *Jan.* 25, *Chercheur de comètes*, 182^{mm}. *Jan.* 27–*Feb.* 11, *Télescope Foucault*, 0·80^{m}.

1867	Marseilles M.T. h m s	No. of ✱	Red. to App. Place s	Red. to App. Place ″	Δ R.A. m s	No. of Comp.	Δ Decl. ′ ″	No. of Comp.	App. R.A. h m s	Parall. s	App. Decl. ° ′ ″	Parall. ″
Jan. 25	8 38 45	1	+0·51	−4·1	−2 35·71	10	+1 16·0	10	2 33 52·64	+0·23	+15 33 34·3	+3·9
25	9 38 6	1	+0·51	−4·1	−2 30·26	3	+2 28·1	3	2 33 58·09	+0·30	+15 34 46·4	+4·1
27	7 4 36	2	+0·50	−4·0	−0 22·91	9	+0 23·2	9	2 37 57·16	+0·09	+16 27 46·5	+3·5
27	7 52 46	2	+0·50	−4·0	−0 18·43	4	+1 21·6	4	2 38 1·64	+0·17	+16 28 44·9	+3·6
28	6 24 56	4	+0·51	−4·0	−1 50·21	10	+0 18·6	10	2 40 2·78	+0·03	+16 54 47·4	+3·4
29	6 57 33	3	+0·49	−3·8	+2 5·72	5	−3 5·4	5	2 42 16·72	+0·08	+17 22 57·5	+3·3
30	6 48 0	5	+0·51	−3·9	−0 49·57	10	+1 51·0	10	2 44 28·22	+0·08	+17 50 1·1	+3·2
31	8 16 55	6	+0·51	−3·9	−1 0·67	10	−1 1·9	10	2 46 50·79	+0·21	+18 18 47·6	+3·4
Feb. 1	6 56 32	7	+0·51	−3·9	−0 54·28	10	+2 57·1	10	2 48 59·40	+0·09	+18 44 2·1	+3·1
2	6 55 51	9	+0·51	−3·8	−0 53·03	5	+2 20·2	5	2 51 17·09	+0·09	+19 10 39·3	+3·0
3	6 51 32	8	+0·50	−3·8	+1 42·03	10	+4 53·7	10	2 53 36·44	+0·08	+19 36 50·1	+3·0
5	7 9 39	16	+0·52	−3·8	−1 2·61	6	−1 40·0	6	2 58 21·92	+0·12	+20 29 6·6	+2·9
7	7 41 51	20	+0·54	−3·7	−1 50·16	5	−4 6·3	5	3 3 15·80	+0·17	+21 20 28·8	+2·8
8	8 39 58	21	+0·52	−3·7	−0 19·63	10	+1 12·1	10	3 5 49·55	+0·25	+21 46 20·5	+3·1
9	7 18 3	22	+0·51	−3·6	+1 27·76	6	−3 15·4	6	3 8 10·42	+0·14	+22 9 38·0	+2·7
10	9 5 58	24	+0·51	−3·6	+1 39·63	5	−2 11·4	5	3 10 52·33	+0·28	+22 35 55·7	+3·1
11	7 56 5	25	+0·51	−3·7	+1 1·09	5	+1 28·8	5	3 13 17·81	+0·19	+22 58 47·0	+2·7

Janvier 25.—La comète a la forme d'une nébulosité ronde, avec un noyau un peu excentrique.

Janvier 26.—La comète a l'aspect d'une nébulosité arrondie, avec un noyau brillant. On distingue assez difficilement une apparence de queue en éventail.

Janvier 27.—La comète a sensiblement le même aspect que le jour précédent.

Janvier 28.—La comète paraît un peu plus faible que le 26, mais le ciel est moins pur.

Janvier 29.—L'apparence de la comète est sensiblement la même que la veille.

Janvier 31.—L'éclat de la comète est un peu moindre que la veille, la queue est dirigée vers l'E. S.E.

Février 1.—L'éclat et l'étendue de la comète ont augmenté en apparence depuis la veille (très beau ciel). Le noyau est plus allongé et plus brillant. La queue, toujours vague, s'étend vers l'E.$\frac{1}{4}$N.E.

Février 5.—La comète est assez belle. Elle semble ne pas avoir augmenté en étendue, mais un peu en éclat.

The Elements I. leave the residuals (O−C) as given in the third and fourth columns of the following table; the fifth and sixth columns show the residuals left by the final elements:—

	Berlin M.T.—aber^{a}.	Elements I. $\Delta\alpha\cos\delta$	Elements I. $\Delta\delta$	Elements III. $\Delta\alpha\cos\delta$	Elements III. $\Delta\delta$
Marseilles	Jan. 25·37593	− 3″·6	−20″·8	+ 3″·1	− 4″·0
„	25·41714	+ 1·9	−18·1	+ 8·6	− 1·4
„	27·31047	− 6·9	−17·2	− 2·2	− 4·4
„	27·34392	− 3·0	−14·5	+ 1·7	− 1·7
„	28·28288	− 5·7	−11·9	− 2·0	− 0·4
„	29·30550	− 2·7	− 7·8	+ 0·1	+ 2·1
Marseilles	Jan. 30·29882	− 5·7	− 8·7	− 3·9	− 0·7
„	31·36052	− 5·6	− 3·1	− 4·9	+ 3·4
„	Feb. 1·30466	− 6·0	− 6·3	− 6·1	− 0·9
„	2·30414	− 6·2	− 1·4	− 6·9	+ 3·0
„	3·30110	− 2·3	− 3·7	− 3·5	0·0
Königsberg	Feb. 4·27786	+ 7·5	− 1·0	+10·7	+ 7·6
„	4·27786	+17·6	+10·9		
Berlin	4·34003	− 4·5	+ 1·7	− 6·3	+ 4·3
Königsberg	4·37520	+15·8	+ 0·2	+14·0	+ 2·8
Vienna	4·39010	−13·4	−17·0	+ 4·6	+ 6·8
„	4·39010	+26·5	+25·4		

	Berlin M.T.—aber^{n}.	Elements I. $\Delta\alpha\cos\delta$	Elements I. $\Delta\delta$	Elements III. $\Delta\alpha\cos\delta$	Elements III. $\Delta\delta$
		″	″	″	″
Leipzig	Feb. 4·43158	+11·3	−10·1	+ 9·4	− 7·5
Berlin	4·44144	− 1·7	− 1·0	− 3·6	+ 1·5
,,	5·29310	− 1·6	−10·7	− 3·8	− 8·8
Leipzig	5·30610	− 0·6	+ 1·0	− 2·8	+ 2·9
Marseilles	5·31360	− 5·5	+ 3·3	− 7·7	+ 5·2
Leipzig	6·29108	− 2·5	+ 1·3	− 4·9	+ 2·4
Durham	6·38425		+13·8		+14·9
,,	6·38692	+19·3		+16·8	
Leipzig	Feb. 7·26669	+ 4·8	+ 1·5	+ 2·0	+ 2·1
Berlin	7·28210	− 2·0	− 9·6	− 4·8	− 9·0
Altona	7·32479	+12·7	+10·0	+ 9·9	+10·5
Marseilles	7·33586	− 3·8	+ 6·5	− 6·6	+ 7·0
Vienna, Josephstadt	7·39926	+13·4	+ 9·5	+10·6	+10·0
Durham	8·36120		−15·1		−15·1
,,	8·36671	+12·3		+ 9·2	
Marseilles	8·37617	− 2·0	+ 1·2	− 5·1	+ 1·2
Vienna, Josephstadt	9·27506	+ 9·5	+ 5·7	+ 6·3	+ 5·3
Leipzig	9·31474	+ 5·7	− 1·4	+ 2·5	− 1·8
Marseilles	9·31924	− 2·4	+ 2·7	− 5·6	+ 2·3
Berlin	9·36226	− 0·1	+ 4·4	− 3·3	+ 4·0
Marseilles	10·39413	− 3·6	+ 9·2	− 6·9	+ 8·4
,,	11·34556	+ 1·9	+ 6·4	− 1·5	+ 5·3
Berlin	Feb. 19·28463	− 3·2	− 4·6	− 6·1	− 6·3
Leipzig	21·30571	+ 9·8	+ 0·7	+ 7·4	− 0·7
Athens	23·31316	+11·9	+13·1	+ 4·6	− 1·7
,,	23·32221	+ 0·8	−14·5		
,,	25·26825	+ 4·6	+18·9	− 2·1	+ 0·3
,,	25·28658	− 6·5	−17·3		
,,	26·30190	+ 1·2	−19·2	+ 1·9	−11·5
,,	26·30917	+ 4·4	−17·8		
,,	26·31813	+ 2·8	+ 3·4		
,,	27·26480	− 0·7	− 6·9	− 1·2	− 6·8
Athens	Feb. 28·30663	+ 1·7	− 3·5	+ 1·5	− 3·2
Leipzig	Mar. 2·32205	− 7·0	− 5·7	− 6·3	− 4·8
Cambridge, Mass.	2·69259	+ 3·1	+ 4·7	+ 4·1	+ 5·8
Vienna	4·34355	− 4·5	+ 1·3	− 2·6	+ 2·9
Athens	8·27622	+11·9	− 8·2	+11·5	+ 0·7
,,	8·28552	+ 4·5	+ 4·3		

	Berlin M.T.—aberr.	Elements I. $\Delta\alpha\cos\delta$	Elements I. $\Delta\delta$	Elements III. $\Delta\alpha\cos\delta$	Elements III. $\Delta\delta$
Cambridge, Mass.	Mar. 26·57464	−12″·8	− 2″·4	− 7″·9	+ 4″·7
,,	28·58127	−12·4	−18·2	− 8·7	−10·9
,,	28·63935	− 8·6	− 7·9	− 4·9	− 0·6
,,	29·58687	+ 6·0	− 9·4	+ 9·3	− 1·9
Cambridge, Mass.	Mar. 30·65261	− 1·3	− 6·8	+ 1·4	+ 0·8
,,	31·63423	+ 7·5	− 3·9	+ 9·6	+ 3·8
,,	Apr. 2·55690	− 3·3	+ 0·7	− 2·4	+ 8·6
,,	3·64152	− 0·4	− 6·9	− 0·1	+ 1·2

From these residuals I graphically constructed the correction of the ephemeris which enabled me to compute the probable error of one observation at the several observatories. Eight normal places were derived, having regard to the weights of the observations, and the corrections of the Elements I. computed. The result is—

T = Jan. 20·22330 Berlin M.T. ± 0·05780

$\omega = 357^\circ\ 3'\ 23''.6 \pm 3'\ 41''.2$
$\Omega = 78\ 28\ 40'.3 \pm 2'\ 8''.1$ — Mean Equinox 1867·0
$i = 18\ 12\ 24'.2 \pm 17''.3$

q = 1·576578 ± 0·001242

a = 11·5054 ± 0·3894

Period = 39·0 years ± 2·0

A glance at the preceding table shows that all the normal places, except the third and fourth, rest almost entirely on observations at one observatory. Besides, as the weight 2 was given to the observations made at Marseilles and to the R.A.'s of the Berlin observations, the fourth normal place and the R.A.'s of the third rest as to three-fourths of their weight on observations of these two observatories. Further, the latter yield the same mean correction of the ephemeris, which is 12″ smaller than the mean of those of the other observations in the third and fourth normal places; therefore, the first four normal places will be influenced by identical systematic errors in the observations of the Marseilles and Berlin observations, and these errors must have an effect on the determination of the orbit—the more so as they obtained a preponderating influence over the last four normal places by the process of weighting. It is worth noting that the residuals left by the last elements in the R.A.'s of the two observatories after January 30 are all negative, the average deviation being 3″·7. Even if only the Marseilles and Berlin observations were taken into account in the first four normal places, they could not be better

represented without introducing unreasonable errors in the other normal places and in the declinations of the Marseilles observations. In order to obviate the influence of systematic errors as much as the unfavourable arrangement of the observations allows, I decided to repeat the determination of the orbit, on the assumption that all the observations are equally accurate, and also that the normal places have the same weight. The details of this computation will be found in the following pages:—

V.

The normal places, as derived from the data give above, are—

Berlin M.T. 1867.	R.A. 1867·0.	Decl. 1867·0.
Jan. 27·0	39° 19′ 21″·2	+16° 19′ 18″·3
Feb. 1·5	42 21 28·1	+18 49 24·5
5·0	44 24 19·2	+20 21 8·7
9·0	46 50 39·6	+22 1 54·9
23·5	56 30 9·7	+27 25 35·1
Mar. 4·0	62 39 58·6	+30 1 18·3
28·5	81 41 15·8	+34 56 4·6
Apr. 1·5	84 51 56·6	+35 22 49·5

I founded the investigation on the following elements:—

ELEMENTS II.

T = Jan. 20·29970 Berlin M.T.

ω = 357° 33′ 36″·9
Ω = 78 25 42·7 } Mean Equinox 1867·0.
i = 18 12 43·1

log q = 0·1981805.

log e = 9·9390823.

The perturbations produced by the action of *Venus*, the Earth, *Mars*, and *Jupiter* were computed at intervals of twenty days, according to Encke's method. They refer to the Equator, and are given in units of the seventh decimal:—

	ξ	η	ζ
Jan. 12·0	− 1·5	− 0·5	−0·2
17·0	− 0·3	− 0·1	−0·1
22·0	0·0	0·0	0·0
27·0	− 0·4	− 0·1	0·0
Feb. 1·0	− 1·3	− 0·3	−0·1
6·0	− 2·8	− 0·5	−0·3
11·0	− 5·0	− 0·7	−0·4
16·0	− 7·7	− 0·7	−0·5
21·0	−10·9	− 0·4	−0·6
26·0	−14·6	+ 0·2	−0·6

	ξ	η	ζ
Mar. 3·0	−18·8	+ 1·2	−0·5
8·0	−23·5	+ 2·8	−0·3
13·0	−28·8	+ 5·0	+0·2
18·0	−34·6	+ 7·9	+0·9
23·0	−40·9	+11·6	+1·9
28·0	−47·9	+16·1	+3·2
Apr. 2·0	−55·6	+21·6	+4·8
7·0	−64·0	+28·1	+6·7
12·0	−73·3	+35·7	+9·1

The polar co-ordinates of the Sun were taken from Le Verrier's Solar Tables in vol. iv. of the *Annales de l'Observatoire de Paris*. The rectangular equatorial co-ordinates contain the foregoing perturbations.

Mean Equinox 1867·0.

Berlin M.T.	☉	B	R
Jan. 27·0	307° 6′ 24″·69	+0″·30	0·9849122
Feb. 1·5	312 41 27·52	+0·51	0·9857133
5·0	316 14 25·27	+0·28	0·9862771
9·0	320 17 28·95	−0·20	0·9869651
23·5	334 54 53·31	+0·38	0·9899779
Mar. 4·0	343 26 41·43	+0·35	0·9921111
28·5	7 48 41·43	+0·57	0·9988647
Apr. 1·5	11 45 31·10	+0·23	1·0000407

	X+ξ	Y+η	Z+ζ
Jan. 27·0	+0·5942010	−0·7205691	−0·3126618
Feb. 1·5	+0·6683568	−0·6646485	−0·2883961
5·0	+0·7123359	−0·6257729	−0·2715289
9·0	+0·7592753	−0·5784476	−0·2509963
23·5	+0·8966005	−0·3850325	−0·1670682
Mar. 4·0	+0·9509819	−0·2593300	−0·1125245
28·5	+0·9895910	+0·1245419	+0·0540428
Apr. 1·5	+0·9790490	+0·1869579	+0·0811240

For computing the coefficients of the equations I employed the formulæ published by Schönfeld in *Astr. Nachr.*, Nos. 2693–95. Schönfeld introduces the variables dT, $d\frac{1}{a}$, dq, and instead of the corrections of ω, Ω, i, $d\kappa = d\omega + \cos i\, d\,\Omega$, $d\lambda = \sin\omega\, di - \cos\omega \sin i\, d\,\Omega$, $d\nu = \cos\omega\, di + \sin\omega \sin i\, d\,\Omega$. But since the differential quotients with reference to κ and T

turned out to be very nearly proportional to each other, I replaced κ by another variable, ι, defined by—

$$d\iota = d\kappa - \frac{k\sqrt{1+e}}{Q_{\frac{3}{2}}^{3}}\,d\mathrm{T}.$$

The differential quotients are then expressed by—

$$\cos\delta\,\frac{da}{d\iota} = \cos\delta\,\frac{da}{d\kappa};\quad \frac{d\delta}{d\iota} = \frac{d\delta}{d\kappa}$$

$$\cos\delta\left(\frac{da}{d\,\mathrm{T}}\right) = \cos\delta\,\frac{da}{d\,\mathrm{T}} + \frac{k\sqrt{1+e}}{Q_{\frac{3}{2}}^{3}}\cos\delta\,\frac{da}{d\kappa}$$

$$\left(\frac{d\delta}{d\,\mathrm{T}}\right) = \frac{d\delta}{d\,\mathrm{T}} + \frac{k\sqrt{1+e}}{Q_{\frac{3}{2}}^{3}}\,\frac{d\delta}{d\kappa}.$$

These quantities may be computed by Schönfeld's formulæ (48) and (49), or from—

$$c\cos\mathrm{C} = \frac{r}{p}(1+e)^{2} - \frac{p}{r};\quad c\sin\mathrm{C} = e\sin v$$

$$\cos\delta\left(\frac{da}{d\,\mathrm{T}}\right) = \frac{\sin\gamma}{\Delta}\,\frac{k}{\sqrt{p}}\,c\cos(g+v+\mathrm{C});$$

$$\left(\frac{d\delta}{d\,\mathrm{T}}\right) = \frac{\sin\gamma}{\Delta}\,\frac{k}{\sqrt{p}}\,c\cos(g'+v+\mathrm{C})$$

in which the notation is the same as in the essay referred to. The numerical values of the coefficients are as follows:—

Right Ascension.

No. of Norm. place.	$d\iota$	$d\,\mathrm{T}$	$d\frac{1}{a}$	dq	$d\lambda$	dv	$\log n$
1	9·91996	1·82541*n*	3·79025*n*	4·96400	9·86027*n*	8·76097*n*	0·6156
2	9·90659	2·03883*n*	4·05739*n*	4·89382	9·84156*n*	9·00369*n*	0·3740*n*
3	9·89949	2·11468*n*	4·17042*n*	4·84217	9·82803*n*	9·10077*n*	0·7279
4	9·89277	2·17121*n*	4·27206*n*	4·77444	9·81097*n*	9·18382*n*	0·5234
5	9·87963	2·21094*n*	4·51355*n*	4·37006	9·73344*n*	9·35446*n*	0·3284
6	9·87863	2·13190*n*	4·60351*n*	3·48039	9·67527*n*	9·39999*n*	0·3998
7	9·88941	1·76044	4·74646*n*	4·68903*n*	9·44371*n*	9·39634*n*	0·2359*n*
8	9·89158	2·00171	4·75755*n*	4·74768*n*	9·39518*n*	9·37949*n*	0·5548

Declination.

1	9·86461	1·26014*n*	3·71464*n*	4·34788	0·05075	8·95145	0·5441*n*
2	9·85446	1·35034*n*	3·96824*n*	4·01987	0·03411	9·19624	9·9031
3	9·84690	1·30735*n*	4·07038*n*	3·52028	0·02318	9·29592	0·4624
4	9·83723	1·14290*n*	4·15753*n*	3·64627*n*	0·01047	9·38332	0·3617
5	9·79169	1·57000	4·32901*n*	4·44038*n*	9·96287	9·58389	0·6902*n*
6	9·75631	1·89467	4·36545*n*	4·56638*n*	9·93386	9·65858	9·6990*n*
7	9·60825	2·25674	4·29596*n*	4·65180*n*	9·84192	9·79455	0·6435*n*
8	9·57594	2·27743	4·26202*n*	4·64189*n*	9·82505	9·80936	0·0000

The coefficients of the equations are given in logarithms. They contain already the factors which allow the elementary corrections to be obtained in their respective units. n denotes the difference (O−C) between the normal places and the positions, computed from the Elements II., multiplied in R.A. by cos δ.

I introduce—

$$x = (9{\cdot}91996)\, d\iota$$
$$y = (2{\cdot}27743)\, d\mathrm{T}$$
$$z = (4{\cdot}75755)\, d\tfrac{\mathrm{I}}{a}$$
$$u = (4{\cdot}96400)\, dq$$
$$v = 0{\cdot}05075\, d\lambda$$
$$w = 9{\cdot}80936\, d\nu\,;$$

Unit of error $= (0{\cdot}7279)$;

and obtain by the Method of Least Squares the normal equations:—

$$\begin{array}{rrrrrrrr}
+7{\cdot}6314\,v & +4{\cdot}1393\,w & +3{\cdot}2527\,y & +1{\cdot}3424\,x & -2{\cdot}6594\,u & -0{\cdot}1189\,z & = & -2{\cdot}4689\\
+4{\cdot}1393\,v & +3{\cdot}7897\,w & +2{\cdot}9356\,y & +0{\cdot}7203\,x & -1{\cdot}5489\,u & +0{\cdot}0193\,z & = & -1{\cdot}7382\\
+3{\cdot}2527\,v & +2{\cdot}9356\,w & +5{\cdot}3242\,y & -1{\cdot}9459\,x & -3{\cdot}7981\,u & -0{\cdot}0700\,z & = & -2{\cdot}4749\\
+1{\cdot}3424\,v & +0{\cdot}7203\,w & -1{\cdot}9459\,y & +11{\cdot}5159\,x & +1{\cdot}7011\,u & -5{\cdot}3272\,z & = & +2{\cdot}3051\\
-2{\cdot}6594\,v & -1{\cdot}5489\,w & -3{\cdot}7981\,y & +1{\cdot}7011\,x & +4{\cdot}2187\,u & +0{\cdot}8315\,z & = & +1{\cdot}9161\\
-0{\cdot}1189\,v & +0{\cdot}0193\,w & -0{\cdot}0700\,y & -5{\cdot}3272\,x & +0{\cdot}8315\,u & +3{\cdot}6572\,z & = & -0{\cdot}9521
\end{array}$$

and further—

$$\begin{array}{rrrrrrrr}
+7{\cdot}6314\,v & +4{\cdot}1393\,w & +3{\cdot}2527\,y & +1{\cdot}3424\,x & -2{\cdot}6594\,u & -0{\cdot}1189\,z & = & -2{\cdot}4689\\
 & +1{\cdot}5445\,w & +1{\cdot}1713\,y & -0{\cdot}0078\,x & -0{\cdot}1064\,u & +0{\cdot}0838\,z & = & -0{\cdot}3990\\
 & & +3{\cdot}0495\,y & -2{\cdot}5122\,x & -2{\cdot}5839\,u & -0{\cdot}0828\,z & = & -1{\cdot}1200\\
 & & & +9{\cdot}2103\,x & +0{\cdot}0398\,u & -5{\cdot}3741\,z & = & +1{\cdot}8147\\
 & & & & +1{\cdot}0952\,u & +0{\cdot}7479\,z & = & +0{\cdot}0714\\
 & & & & & +0{\cdot}0008\,z & = & +0{\cdot}0106
\end{array}$$

The variables expressed in functions of z and of $d\frac{\mathrm{I}}{a}$ become—

$$u = +(8{\cdot}8142) - (9{\cdot}83493)\, z \qquad dq = +(4{\cdot}5781) - (9{\cdot}62848)\, d\tfrac{\mathrm{I}}{a}$$

$$y = -(9{\cdot}1759) - (8{\cdot}8396)\, z \qquad d\mathrm{T} = -(7{\cdot}6263) - (1{\cdot}3197)\, d\tfrac{\mathrm{I}}{a}$$

$$x = +(9{\cdot}2939) + (9{\cdot}76821)\, z \qquad d\iota = +(0{\cdot}1018) + (4{\cdot}60580)\, d\tfrac{\mathrm{I}}{a}$$

$$v = -(9{\cdot}2922) - (9{\cdot}43368)\, z \qquad d\lambda = -(9{\cdot}9694) - (4{\cdot}14048)\, d\tfrac{\mathrm{I}}{a}$$

$$w = -(9{\cdot}1436) - (8{\cdot}6631)\, z \qquad d\nu = -(0{\cdot}0622) - (3{\cdot}6113)\, d\tfrac{\mathrm{I}}{a}.$$

These quantities substituted in the original equations give the following equations of the form $Ad\frac{I}{a}=N$:—

Right Ascension.

	1	2	3	4
N	+ 1″·70	− 4″·92	+ 2″·75	+ 0″·71
A	−91	+126	+183	+184
	5	6	7	8
N	− 0·37	+ 0·24	− 2·83	+ 2·73
A	−215	−512	−74	+306

Declination.

	1	2	3	4
N	− 3″·44	+ 0″·95	+ 3″·12	+ 2″·62
A	−631	−10	+231	+392
	5	6	7	8
N	− 4·12	+ 0·58	− 2·61	+ 2·85
A	+331	+118	−251	−275

The residuals become a minimum for $\log d\frac{I}{a}=7\cdot3885-10$. The corrections to be applied to Elements II. are therefore—

$$dT=-0\cdot05531$$
$$d\omega=-2'\,22''3$$
$$d\Omega=+1\;52\cdot6$$
$$di=-\;\;9\cdot6$$
$$\log dq=7\cdot01543\,n$$
$$\log d\frac{I}{a}=7\cdot3885.$$

They reduce $[nn]=160''$ to $[nn6]=104''$, and the mean error of the normal place becomes $\epsilon=\pm3''\cdot2$.

Adding the foregoing corrections to the Elements II., I get the definitive elements, which I give along with their probable errors:—

Elements III.

$T=1867$, Jan., 20·24439, Berlin M.T.		±0·06026 (±0·01748)
$\omega=357^\circ\;31'\;14''\cdot6$	Mean Equin. 1867·0	±3′ 38″·2 (± 43″·1)
$\Omega=\;78\;\;27\;\;35\cdot3$		±2 2·2 (± 5·9)
$i=\;18\;\;12\;\;33\cdot5$		± 12·6 (± 5·4)
$q=1\cdot577231$		±0·001175 (±0·000034)
$a=11\cdot7138$		±0·3790
Period = 40·1 years		±2·0
$\log e=9\cdot9371930$		

The figures in brackets show the probable error if a be considered constant.

These elements represent the normal places, thus:—

	Direct Computation.		Computed from the Equations.	
	$\Delta\alpha \cos\delta$	$\Delta\delta$	$\Delta\alpha \cos\delta$	$\Delta\delta$
1867.				
Jan. 27·0	+2″·0	−1″·8	+1″·9	−1″·9
Feb. 1·5	−5·1	+1·0	−5·2	+1·0
5·0	+2·3	+2·6	+2·3	+2·5
9·0	+0·3	+1·7	+0·3	+1·7
23·5	+0·2	−4·9	+0·2	−4·9
Mar. 4·0	+1·6	+0·3	+1·5	+0·3
28·5	−2·5	−2·0	−2·6	−2·0
Apr. 1·5	+2·1	+3·5	+2·0	+3·5

VI.

It will be noticed that the definitive elements agree within the limits given by their probable errors with those derived on the assumption of different weights (§ IV.). This agreement becomes still closer if the elements be reduced to the same period. It remains to be shown how much the period may be varied without doing violence to the observations. The following table contains the residuals left in the normal places by the definitive elements when the period lies between twenty-five and seventy years:—

Right Ascension.

Period in Years.	25	30	35	37	39	40	41	43	45	50	55	70
	″	″	″	″	″	″	″	″	″	″	″	″
1	+ 4·9	+ 3·7	+2·7	+2·4	+2·1	+2·0	+1·9	+1·6	+1·4	+0·9	+0·5	− 0·4
2	− 9·1	− 7·4	−6·1	−5·7	−5·3	−5·1	−4·9	−4·6	−4·3	−3·6	−3·1	− 1·8
3	− 3·5	− 1·0	+0·8	+1·4	+2·0	+2·3	+2·5	+3·0	+3·5	+4·4	+5·3	+ 7·1
4	− 5·5	− 3·0	−1·2	−0·6	0·0	+0·3	+0·5	+1·0	+1·5	+2·5	+3·3	+ 5·2
5	+ 7·0	+ 4·1	+1·9	+1·2	+0·5	+0·2	−0·1	−0·6	−1·2	−2·3	−3·3	− 5·5
6	+17·7	+10·9	+5·7	+4·0	+2·4	+1·7	+0·9	−0·4	−1·6	−4·4	−6·7	−12·0
7	− 0·2	− 1·2	−1·9	−2·1	−2·4	−2·5	−2·6	−2·8	−3·0	−3·4	−3·7	− 4·5
8	− 7·6	− 3·5	−0·4	+0·7	+1·6	+2·1	+2·5	+3·3	+4·0	+5·7	+7·1	+10·1
[vv]	569	228	86	63	51	49	48	53	64	108	169	377

Declination.

Period in Years.	25	30	35	37	39	40	41	43	45	50	55	70
1	+18·1	+ 9·7	+3·3	+1·2	−0·8	−1·7	−2·6	−4·3	−5·8	−9·2	−12·0	−18·5
2	+ 1·3	+ 1·2	+1·1	+1·0	+1·0	+1·0	+1·0	+1·0	+0·9	+0·9	+ 0·8	+ 0·7
3	− 4·7	− 1·6	+0·7	+1·5	+2·2	+2·6	+2·9	+3·5	+4·1	+5·3	+ 6·4	+ 8·7
4	−10·7	− 5·4	−1·5	−0·1	+1·1	+1·7	+2·2	+3·2	+4·2	+6·3	+ 8·1	+12·1
5	−15·3	−10·9	−7·6	−6·5	−5·4	−4·9	−4·5	−3·6	−2·8	−1·0	+ 0·5	+ 3·9
6	− 3·5	− 1·8	−0·7	−0·3	+0·1	+0·3	+0·4	+0·8	+1·0	+1·7	+ 2·2	+ 3·4
7	+ 5·9	+ 2·6	0·0	−0·8	−1·6	−2·0	−2·3	−3·0	−3·6	−4·9	− 6·1	− 8·7
8	+12·2	+ 8·5	+5·7	+4·8	+3·9	+3·5	+3·2	+2·4	+1·8	+0·3	− 1·0	− 3·8
[vv]	896	328	106	71	55	54	57	70	94	181	294	682

In spite of the inferior quality of the observations and the unfavourable arrangement, one may safely assume that the period will not be beyond the limits thirty and fifty-five years, but will lie most probably between thirty-five and forty-five years. This fixes the time of the comet's next appearance between 1902 and 1912.

In the next table are shown the geocentric positions of the comet and its brightness (*I.*) on twelve days of the year for five points of its orbit.

		Jan. 0.	Feb. 1.	Mar. 5.	Apr. 6.	May 8.	June 9.	July 11.	Aug. 12.	Sept. 13.	Oct. 15.	Nov. 16.	Dec. 18.
64 days before Perihelion Passage	R.A.	$0^{h}\cdot5$	$0^{h}\cdot8$	$1^{h}\cdot4$	$2^{h}\cdot0$	$2^{h}\cdot7$	$3^{h}\cdot5$	$4^{h}\cdot2$	$4^{h}\cdot7$	$4^{h}\cdot9$	$3^{h}\cdot9$	$1^{h}\cdot7$	$0^{h}\cdot6$
	Decl.	$-11°$	$-6°$	$-1°$	$+4°$	$+8°$	$+10°$	$+11°$	$+10°$	$+6°$	$-5°$	$-16°$	$-14°$
	I.	0·4	0·2	0·2	0·1	0·1	0·2	0·2	0·3	0·6	1·3	1·3	0·6
32 days before Perihelion Passage	R.A.	$1^{h}\cdot4$	$1^{h}\cdot5$	$2^{h}\cdot0$	$3^{h}\cdot3$	$3^{h}\cdot4$	$4^{h}\cdot2$	$5^{h}\cdot0$	$5^{h}\cdot7$	$6^{h}\cdot2$	$6^{h}\cdot1$	$4^{h}\cdot0$	$1^{h}\cdot7$
	Decl.	$-2°$	$+2°$	$+6°$	$+11°$	$+14°$	$+17°$	$+18°$	$+17°$	$+16°$	$+11°$	$+2°$	$-3°$
	I.	0·9	0·4	0·3	0·2	0·2	0·2	0·2	0·3	0·6	1·3	2·9	1·4
Perihelion Passage	R.A.	$2^{h}\cdot9$	$2^{h}\cdot4$	$2^{h}\cdot8$	$3^{h}\cdot4$	$4^{h}\cdot2$	$5^{h}\cdot1$	$5^{h}\cdot9$	$6^{h}\cdot7$	$7^{h}\cdot4$	$7^{h}\cdot8$	$7^{h}\cdot1$	$3^{h}\cdot8$
	Decl.	$+15°$	$+13°$	$+15°$	$+18°$	$+21°$	$+22°$	$+23°$	$+23°$	$+21°$	$+20°$	$+21°$	$+18°$
	I.	2·2	0·8	0·4	0·3	0·2	0·2	0·2	0·3	0·4	0·8	2·4	3·3
32 days after Perihelion Passage	R.A.	$6^{h}\cdot0$	$3^{h}\cdot8$	$3^{h}\cdot8$	$4^{h}\cdot3$	$5^{h}\cdot1$	$6^{h}\cdot0$	$6^{h}\cdot8$	$7^{h}\cdot7$	$8^{h}\cdot5$	$9^{h}\cdot0$	$9^{h}\cdot2$	$7^{h}\cdot6$
	Decl.	$+38°$	$+29°$	$+26°$	$+26°$	$+27°$	$+27°$	$+26°$	$+25°$	$+24°$	$+22°$	$+25°$	$+35°$
	I.	2·9	1·2	0·5	0·3	0·2	0·2	0·2	0·2	0·3	0·4	1·0	2·6
64 days after Perihelion Passage	R.A.	$9^{h}\cdot5$	$6^{h}\cdot4$	$5^{h}\cdot2$	$5^{h}\cdot4$	$5^{h}\cdot9$	$6^{h}\cdot9$	$7^{h}\cdot7$	$8^{h}\cdot5$	$9^{h}\cdot3$	$9^{h}\cdot8$	$10^{h}\cdot4$	$10^{h}\cdot1$
	Decl.	$+38°$	$+45°$	$+37°$	$+33°$	$+32°$	$+30°$	$+28°$	$+26°$	$+24°$	$+22°$	$+23°$	$+32°$
	I.	1·4	1·3	0·6	0·3	0·2	0·2	0·1	0·1	0·2	0·3	0·4	1·0

The brightness at the time of its discovery has been taken as unity. At the time of the last observation the computed intensity was $I=0\cdot3$, when it was a difficult object in the 15-inch Refractor of Harvard College Observatory. Its rediscovery may therefore be expected if it passes its perihelion between September and April.

Notes on some Star Photographs recently taken at Sydney Observatory. No. 2. By H. C. Russell, B.A., F.R.S., Government Astronomer.

It will be remembered that in the November number of the *Monthly Notices* I gave an account of the Milky Way about *η Argûs*, and stated that the photograph was *under-exposed*. On several occasions since I have tried longer exposures with the same camera and plates (Ilford Extra Rapid), getting better results as the time of exposure increased.

I have at last got an exposure of eight hours on a fine clear night, and this makes the whole aspect of this part of the Milky Way so different that I send glass and paper positives of it, which should be compared with those sent before to fully realise the enormous difference which the increased exposure and clearer night have made. In comparing the plates it is necessary to remember that the camera slide has been turned 90°, and, therefore, the long way of the plate is now north and south.

I have not attempted as yet a general count of the two photographs, but there is obviously a great number of additional stars, and hence it is not to be wondered at that the whole aspect of the Milky Way about *η Argûs* appears changed, and at the same time it is satisfactory to note that little details, dark spots and lines, visible in the fainter negative are reproduced in this; the nebula itself is much brighter, and the details more defined, the outlying wreaths of nebula extending over a much wider space than has appeared in any drawing or previous photograph. This feature is best seen in the paper print of this object made from the *portrait camera negative* No. 81, which was exposed eight hours. In that photograph the great rift which divides the nebula seems to originate in an oval dark space and passes thence upwards and towards the preceding side, passing first between two well-marked clusters of stars; thence it passes another cluster on the left, and at the third cluster it turns away to the left; it is quite evident also that the nebulous matter here is bounded by this dark rift, and includes the middle cluster on the left, which is an extension in this direction four times as far as Herschel traced it with his reflector at the Cape. Starting again from the rift near the dark oval and going south, the nebula is extended nearly as far again as Herschel saw it, and

the parallel curved wreaths of nebula are much more distinct than in my earlier photographs, but still seem to want longer exposure.

In the dark oval space which lies near the southern extremity of the nebula no increase of exposure suffices to show any nebulous light whatever.

I have also made a number of long exposures on η *Argûs* with the "Star Camera" (11 feet $3\frac{1}{2}$ inches focus), and succeeded, as the accompanying glass and paper prints will show, in proving that the central part of the nebula about this star has a most complex structure, of the same character as that about θ *Orionis*; but although the greater space given to the nebula in this camera makes the separation of these details possible, I have not yet succeeded in getting so dense and extended a picture of it as I get with the portrait camera, although I have tried one American and another English make of plates; indeed, neither of these makers' plates, judged by the sample I have received, is so sensitive as that which I have been using.

I have compared the plates by having the two cameras side by side on the same stand and pointing to the same place, and then with plates to be compared one in each camera, giving them the same exposure; I had first determined by many trials that the two cameras are about equally powerful.

In the contact print from negative No. 77 it will be seen that the nebula extends but little beyond the well-known oval in the south of it, while in the prints from the portrait camera negative No. 81 the nebula may be seen to extend much farther, and the extension along the great rift spoken of as visible in the photographs from the portrait camera is not to be traced here, but the great dark oval not noticed by Herschel appears very conspicuously in a number of the photographs that I have taken, and must be a feature of the object; it is near the centre of the whole nebula and at the end of the great rift.

It was in this dark oval space that one of the brightest and most conspicuous parts of the nebula was situated when Herschel was at the Cape, and the fact that it has wholly disappeared is a significant commentary on the wisdom of the course which he adopted, in not only drawing but in marking out by conspicuous stars, and by descriptive letter-press, portions of the nebula which were well defined and conspicuous.

The part of the nebula referred to was situated about the intersection of the lines $+50^s$ and $+3000$, and in studying and re-mapping this nebula in 1871 I noticed that this portion was missing. I called attention to it then, but as the telescope I used was of only $7\frac{1}{4}$ inch aperture it could hardly be assumed as proven. Later I failed to find it with the $11\frac{1}{2}$-inch refractor, and it is still invisible in the best of my photographs, which show fainter nebulæ and hosts of stars which Herschel could not see. It is in many respects the most remarkable part of Herschel's drawing, and at p. 39 of the letter-press, after

pointing out the care he had bestowed in laying down parts of the nebula which were well defined by carefully measuring stars situated on or about their edges, and which was done with the expressed object of detecting any change in the nebula, or, to use his own words, "will serve as excellent detectors of change in its form should any occur;" and again, "so situated that the slightest shifting of the nebulous contour at its preceding side cannot fail to be rendered visible;" and then referring to one conspicuous point of the now missing part, he says, "Similarly the star O, No. 803, and O1, No. 813, one on each side of the remarkable nebulous projection whose co-ordinates $+25^s$ and *—2500 pts. afford means of ascertaining any relative movement in this part of it." In other parts of this great nebula these descriptive paragraphs accurately describe the features as they are to-day; and even here the stars are visible, but in the part under discussion there is no such nebula as he describes, either with our equatoreal of 11½ inch aperture, or in these photographs. As a means of estimating how much more powerful in grasping faint objects these photographs are than Herschel's large reflector, I may mention that he carefully scanned the great oval in the southern part of the nebula, and records that he saw four very faint stars in it. My negative, No. 77, shows twenty stars in the same space, and in the lemniscate which attracted his very close attention, and where he saw *one star*, my negative shows ten stars. We have here, therefore, the strongest evidence that a well-defined and brilliant portion of the nebula about *η Argûs* has disappeared between the years 1837 and 1871, when I first noticed that it was gone.

During March 1891 I have taken photographs with a view of tracing the Milky Way in the great rift which Herschel shows right across it in *Argo*, and here, as I have found in other parts, the eye and the camera differ very much.

It will be seen that the three photographs sent (paper and glass positives of each herewith) cover most of the rift in question, and the rough diagram sent herewith of the Milky Way, on the same scale as the photographs copied from Herschel and Proctor, will make the comparison easier. On it the spaces covered by the plates are marked in red ink, and the scales of the photographs and diagram are roughly the same.

The centre of plate 65 is in the preceding point of the four remarkable projections of the Milky Way; its centre is in R.A. $7^h\ 50^m$, and Dec. 47° 47′, and it covers from Dec. 40½° to 54°, thus taking in at least 4° beyond the remarkable point in the drawings, and it is covered with stars almost uniformly, although the eye sees no Milky Way in that part of the sky covered by the southern end of this plate; or, in other words, the Milky Way here, as seen by the camera, extends right across the rift which to the eye appears void of stars. Similarly plate 73 shows the stars almost uniformly over the plate which here

* This is a misprint; the sign should be +. See position of stars.

covers not only the Milky Way space but the whole of the great rift between R.A. 8^h 10^m and 9^h 10^m, or, in other words, completely across the rift shown in the best drawings. The centre of No. 73 is in R.A. 8^h 37^m and Dec. 46° 53′ S., and it extends from 40° to 54° S. Dec., and taking this with No. 65, the whole of the rift from 7^h 20^m to 9^h 10^m is found to be as thickly studded with stars and star-dust as the neighbouring parts figured on the best star maps. By comparing the overlapping parts of Nos. 65 and 73 it will be seen that 73 does not show quite so many stars as it should, the night it was taken not being so clear as the night on which No. 65 was taken. Plate No. 68, again, shows a band of stars extending completely across the rift from R.A. 10^h 10^m to R.A. 10^h 30^m. The night when this plate was taken was not a very good one, and hence probably here also the stars are not so numerous as they ought to be. On February 9, 1891, the night being very clear, a negative of *Nubecula Major* about 30 *Doradus*, with 6^h 17^m exposure, was taken with the Star Camera, 11 feet 3½ inches focus. In this negative the central part of the nebula is over-exposed, but the surroundings show out faintly as a most complex structure, and are fairly reproduced in the thin contact print No. 2; their extent is at least eight times as great as that which the central mass covers when seen through the telescope. These faint outlying portions are of the same character as the parts visible to the eye; that is, a series of loops arranged symmetrically with regard to the central mass: the greatest extension is on the preceding side, where it stretches out nearly three times the width of the part seen with the telescope, and on the south side there can be traced very faintly a large oval dark space outlined by the nebula and as long as the whole of the central mass.

In No. 1 these features of the nebula have been sacrificed to make the stars bright on a black ground. The arrangement of the stars here is most unusual; the great groups are very concentrated, without any signs of spiral structure, and these clusters, all of which are elongated, are roughly parallel with each other, and separated by dark bands, which, however, are not without stars. I have not seen a similar structure in any other part of the heavens, and the stars are much closer together than usual. In places they number at the rate of 5,000 or 6,000 to a square degree, so that it is not surprising to find the dense parts run into blotches of light when photographed with the portrait camera.

On these Star Camera plates $1° = 2^{in}\cdot360$, and on those taken with the portrait camera $1° = 0^{in}\cdot556$.

The photographs are placed in the Library.

Examples of Comparative Photographs of the Metallic and Solar Spectra. By F. McClean, M.A.

The photographs represent the spectra of Sections IV., V., and VI. of the Gold Group of Metals and of Section IV. of the Iron Group. These spectra are collated by means of their common air lines with the iron spectrum, and so by means of the iron lines with the solar spectrum.

The sections correspond with the divisions of Ångström's Chart. Section VI. extends to wave-length 5720 (a little short of D), which is as far towards the Red as the photographs can be, at present, satisfactorily obtained. The exposure requisite with the more refractory metals is something like sixty times as long as is necessary for photographs of the corresponding portions of the solar spectrum, although an extremely powerful induction spark is used.

These photographs are probably among those which offer the greatest difficulty in the series of metallic spectra now in hand, and as the undertaking is one requiring considerable time and labour, I wished meanwhile to bring these examples of the work before the Society.

The spectra of the metals appear to me to be fairly within the scope of astronomy, as our knowledge of them forms the basis of any knowledge we possess of the composition of the heavenly bodies.

The spectra of the Gold Group, as far as the photographs go, indicate many lines due to these metals not hitherto observed, and they also show some curious coincidences between the air lines in the metallic spectra and lines in the solar spectrum.

1891 *June* 11.

Observations of the Partial Solar Eclipse of 1891 *June* 6, *made at the Radcliffe Observatory, Oxford.*

(*Communicated by E. J. Stone, M.A., F.R.S.*)

The observations of first contact were lost owing to cloud. The last contact was satisfactorily observed.

Greenwich Mean Time. h m s	Observer.	Instrument.	Power.	Ref.
6 22 46·4	Wickham	Barclay, 10-inch	90	(*a*)
6 22 47·8	Robinson	Heliometer, 7½-inch	140	(*b*)

(*a*) The time given is that of the last trace of the Moon's limb: phenomenon slow, limbs undulating, but observation good.

(*b*) The time noted is that of the final disappearance of the Moon's limb; observation considered very fair.

Radcliffe Observatory, Oxford:
1891 *June* 11.

Observations of the Transit of Mercury on 1891 May 9 at the Royal Observatory, Edinburgh.

(*Communicated by Ralph Copeland, Ph.D., Astronomer Royal for Scotland.*)

The sky was very clear in the neighbourhood of the Sun, and at a moderate elevation the definition was excellent as tested before the egress on *Jupiter*, and afterwards on various sun-spots. But at the very low altitude of *Mercury*, which was only 2° 44′ above the true horizon at internal contact, the case was far different. Examined with the 24-inch reflector, and a power of 138 on 4 inches of free aperture just clear of the diagonal mirror, the Sun's limb was deeply indented with slow, creeping undulations. Some of these indentations occasionally deformed the same point of the Sun's margin for a second or more at a time, giving it a kind of scolloped appearance. From comparisons with the planet's diameter, it was estimated that the larger of these indentations were fully 3″ deep. They differed very much in length, but 1′ may be taken as the average; some, however, were quite as short as 12″, and the crest of one of these short waves was seen to turn over for a second or so into a distinct hook almost enclosing a dark area not unlike the disc of the planet. The undulations seemed chiefly to move along the Sun's limb in the direction of decreasing position-angle, that is to say, downwards, the position-angle of the planet counted from the Sun's vertex being 223°.

As seen in the reflector, the Sun's limb appeared to be torn asunder rather suddenly by the planet's disc at $19^h\ 40^m\ 40^s$ sidereal clock time, but the outline of the Sun was so unsteady that for about a quarter of a minute it looked as if the Sun's limb might reunite at any moment; but this did not happen, and the above time was adopted as that of internal contact.

At external contact the Sun's limb was watched for 22^s after the recorded time, but no further trace of the planet was seen. The planet's true altitude at this contact was 3° 17′.

Mr. Heath observed with his own 3½-inch Cooke achromatic, while Mr. A. J. Ramsay used the 3·7-inch Sheepshanks telescope, reduced in aperture, on a portable equatorial stand.

The observations, arranged in order of time, run as follows:—

	Edinburgh M.T.	Effective Aperture.	Power.	Observer.
	h m s	ins.		
Internal contact ...	16 28 50·1	4	138	R. C.
„ ...	16 28 58·1	2⅞	48	A. J. R.
Planet bisected ...	16 31 4·7	4	138	R. C.
„ ...	16 31 51·6	3½	120	T. H.
External contact ...	16 32 49·4*	2⅞	48	A. J. R.
„ ...	16 33 9·4	3½	120	T. H.
„ ...	16 33 42·3	4	138	R. C.

* Observer's Note: 'The last contact was estimated to have taken place when I could no longer distinguish between the undulations of the Sun's limb and the notch made by the disappearing planet.'

The Transit of Mercury, 1891 *May* 9, *observed at Sydney Observatory.*

(*Communicated by H. C. Russell, B.A., F.R.S., Government Astronomer.*)

The Transit of *Mercury* was satisfactorily observed here to-day. The day was beautifully fine and almost cloudless, but owing to a sudden change of temperature due to a cold southerly wind the definition was not steady. The observations of ingress and egress were made by Mr. R. P. Sellars, who used the large refractor, 11½ O.G., and polarising eyepiece with power of 100. At ingress external contact was observed at $9^h\ 59^m\ 36^s{\cdot}8$.

	h	m	s
Internal contact	10	3	36·8
At egress Internal contact	2	50	43·2
At egress External contact	2	55	21·2

The last contact was considered the most satisfactory, definition being at that moment remarkably good. During the passage thirty-eight micrometer measures were made of the planet's position, and twenty photographs were taken on a scale which makes the Sun's diameter 5¼ inches. These are not yet measured or reduced. At noon, as the Sun passed the meridian, both limbs and *Mercury* were observed over seven wires.

I used the finder of the astrophotographic telescope with O.G. 7½ inches. This instrument is in an out-building almost at the ground level, and in it the faulty definition due to atmospheric causes was much worse than in the 11½-in. equatoreal, the latter being raised above the ground 30 feet. Satisfactory observations of ingress could not be made owing to the wavy outline of the Sun at external contact and black drop phenomena at internal contact. The time when I was sure the indent at external contact was *Mercury* was $10^h\ 0^m\ 5^s{\cdot}46$, and the internal contact $10^h\ 4^m\ 1^s{\cdot}76$, but I am sure both these times are late. The egress I was unable to observe. Mr. H. A. Lenehan, first assistant, observing at his own house with a 3-in. telescope, saw external contact at ingress at $9^h\ 59^m\ 45^s{\cdot}0$. Mr. G. D. Hirst, observing at his own house, saw egress with a 3¾-in. equatoreal reduced to $2\frac{7}{10}$ in., and dark blue shade, found it impossible to determine the true contact of limbs within 10 seconds owing to the formation of a well-marked black drop, which in the drawing is in length equal to half the diameter of *Mercury*.

Sydney Observatory:
1891 *May* 10.

Observations of the Transit of Mercury, 1891, May 9.

By Professor Kavasgee D. Naegamvala.

The Transit of *Mercury* of May 9 last was observed here on the morning of May 10, civil time. The telescope employed was a Newtonian Reflector (with the silvering removed from the glass parabolic mirror) of $16\frac{1}{2}''$ aperture. No solar eyepiece was used, but a Pritchard's wedge was interposed between the ordinary Huyghenian eyepiece and the eye. The power employed almost throughout was about 130 diameters, as it was found inadvisable to use even the next higher power available, owing to the atmospheric conditions being not of the very best. The limb of the Sun was never observed perfectly quiescent, but throughout it appeared more or less tremulous.

The first part of the transit was not observed, as the Sun rose some time after ingress.

The form of the planetary disc during transit appeared to be circular and of a very inky colour, and comparatively much darker than the brownish-black umbra of the large sun-spot then visible on the luminary.

No inner bright spot was seen on the planet's disk, as noted by most of the previous observers,* but the aureola of light surrounding the disc was, on the other hand, well seen. The aureola was circular, and the thickness of the ring of light was estimated by the eye to be about two-thirds the diameter of the disc itself. It was, moreover, decidedly brighter than the general surface of the Sun, though the intensity of the illumination slightly fell off at the margin of the ring. I may remark that the aureola was best seen when the darkest part of the Pritchard wedge was interposed, and was gradually lost sight of as the wedge was shifted and its lighter portions brought opposite to the eye, even when the depth of colour of the wedge was sufficient to enable the general surface of the Sun to be observed, not only with complete safety, but also with comfort. More than once I had a feeling that the aureola was slightly coronal in character, but I don't lay any stress on it. The aureola was seen up to a very short time of the internal contact at egress, but I did not exactly note the time of its disappearance, as my attention was then directed more to the first formation of the bright ligament and black drop, if any.

The bright ligament was sharply formed, and when just broken the planet's disc at once assumed a pear-like shape. Within two or three seconds, however, a very curious phenomenon was observed. A smaller pear (so to call it), about one-

* The previously recorded observations of the 'bright spot,' as far as I am aware, were all taken with *refractors*, with the exception of a single one, *vide Monthly Notices*, R.A.S., vol. xxix., p. 57, and a doubt, more than once expressed by astronomers, that the phenomenon was an optical one.

third the size of the other and of a lighter tint (i.e. *less black*), was seen to hang outside the limb of the Sun, the "pears" being attached together by their necks in one line. This lasted for about half a minute. The disc of the egressing planet next took the form of a half ellipse, with the semi-minor axis more or less radial; while just before external contact the disc assumed the form of a short and very flat dummy truncated cone with the apex towards the centre of the Sun. The height of the cone gradually grew less and less, till the planet was completely lost to view. The actual external contact was not well observed, owing to the tremulous state of the Sun's limb. For this reason also no time-observations with the chronograph were taken.

The planet could not be observed after egress, though a very careful search was made for it. No appearance resembling that of a satellite was noted during the transit, but it must be remarked here that I was throughout unfortunately prevented from using high powers through unfavourable atmospheric conditions.

The Observatory, College of Science,
Poona, India: 1891 *May* 15.

Note.

Father de Penaranda, Director of the Observatory of the St. Xavier's College, Calcutta, has issued his report, a newspaper reprint of which I beg to enclose. The colour of the planet therein is designated as being of "an intense *purple*-black," while my impression was that it was *inky*-black. The wedges employed by me were alternately two: one that I had received directly from Professor Pritchard, during my visit to European observatories in 1884, and the other was the one I had at the same time purchased from Mr. Hilger. Both of them are of excellent neutral tint; while I am not aware what means were employed by Father de Penaranda to modify the light of the Sun.

Poona: 1891 *May* 21.

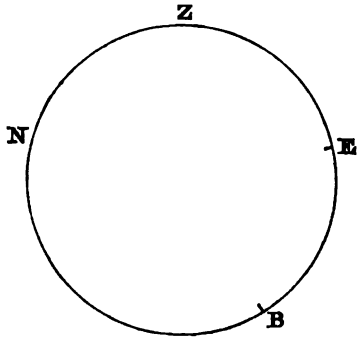
The Transit of Mercury. By the Rev. A. de Penaranda, S.J.

(*Communicated by Prof. K. D. Naegamvala.*)

The Transit of *Mercury* was fairly well observed at St. Xavier's College Observatory, Calcutta, and some good photographs were obtained. The weather, although not all that could have been desired, was more favourable than one would have expected at this season of the year. After a stormy evening and a boisterous night, the Sun rose glorious in a clear sky, and found the three astronomers at their posts making the last adjustments. Both the small and the large equatoreal were put in requisition; the latter, by a special arrangement, giving both a direct and a projected image. The ingress, although visible, could scarcely be said to be properly observable. The Sun then being little more than 5° above the horizon, the boiling at this low altitude was such that it resembled the waves of an agitated sea, among which the tiny black dot's presence could be guessed rather than seen. As far as could be observed or estimated, it was slightly *behind time*, the first external contact taking place at about $5^h\ 51^m$, instead of $5^h\ 50^m\ 3^s$. At egress, the internal contact, despite the very annoying interference of clouds, could be more satisfactorily timed. In fact, there was here a wonderful and rare consensus to the last second of all the observers; from which it appears that the planet now was slightly *before its time*, reaching the Sun's western limb at $10^h\ 17^m\ 17^s$, instead of the computed $10^h\ 18^m\ 49^s$—a difference of $1^m\ 32^s$. Combining this priming with the lagging at ingress, the whole transit seems to have lasted from 2 to $2\frac{1}{2}$ minutes less than computed. This small error of 2 minutes on nearly 5 hours may be accounted for either by some slight imperfection in the astronomical tables of *Mercury*, or by some small excess in the adopted magnitude of the Sun's apparent diameters; or is perhaps owing to a combination of both causes. The planet's aureola was distinctly seen of a decided yellow tinge; the planet itself appearing of an intense purple-black; whereas the spots—even their nuclei—seemed rather of a brownish and notably less deep black. This does not appear to be a mere optical illusion due to contrast, as the photographs bear traces of it. *Mercury*, though to the sight much darker than any nucleus and larger than most of them, but purple, is only slightly marked on the photographs; while small spots, though lighter in colour, but brownish, are much more strongly indicated. The time of the internal contact at ingress could only be approximately estimated on account of the agitation of the Sun's limb; the external contact at egress could not be observed, the Sun being covered by clouds.

On the Transit of Mercury as seen at the G. V. Juggarow Observatory, Daba Gardens, Vizagapatam, May 10, 1891. By A. V. Nursingrow.

The annexed diagram represents the disc of the Sun at the time of the transit, as visible to an observer at Vizagapatam, for direct image.



Z represents the vertex or the highest point of the Sun's disc.

N the north point.

B the point of first contact.
E the point of last contact. } Both internal.

The longitude of the Observatory $=5^h\ 33^m\ 30^s$ E; the geographical latitude $=17°42'9''$ north; and the geocentric latitude $17°35'36''{\cdot}6$.

Clouds were covering the Sun up to $6^h\ 10^m$. When the Sun became visible, we observed that *Mercury* had advanced some distance from the edge of the Sun's disc. The rest of the transit was seen undisturbed by clouds.

The planet was seen as an intensely dark spot when compared with the nuclei of the solar spots then visible.

We did not find a ring of faint light round the planet, neither did we see a wavy tint of light darting from the upper edge of its disc as we noticed during the transit of 1868, p. 278, vol. xxix., *Monthly Notices of the Royal Astronomical Society*, 1869. The telescope now used is a 6-inch refractor by Messrs. Cooke and Sons, equatorially mounted under a revolving dome.

During the whole transit, the planet appeared as a circular dark spot on the Sun's disc. We did not observe that its contour became pear-shaped just before egress; but on reaching the edge of the Sun's disc, it formed a dent quite circular on the

limb. This we took for internal contact at egress = $10^h17^m11^s{\cdot}1$ Vizagapatam mean time (civil reckoning). The planet's bisection was observed=at $10^h\ 19^m\ 38^s{\cdot}6$, and the external contact at egress at $10^h\ 22^m\ 6^s{\cdot}8$.

Observatory, Daba Gardens,
Vizagapatam.

Probable Early Observation of an Immersion of Titan.

By Rev. S. J. Johnson.

The observation of a disappearance of *Titan* in *Saturn's* shadow (an event which might again have been witnessed this evening but for intervening clouds), made by Dawes in 1862, was regarded at the time as unique. But in Simonelli's "Scientia Eclipsium," vol. iv. p. 180, there seems to be mention of such a phenomenon being noticed by J. Cassini in 1715. The passage runs as follows: "IV Satelles 1711 die 12 Augusti spectante Blanchino per horam et amplius non apparuit cœlo serenissimo. Certior hujusmodi eclipsis observata fuit a C. J. Cassino in quarto satellite die 25 Martii an. 1715, hor. 11."

Melplash Vicarage, Dorset,
June 6.

Data for computing the positions of the Satellites of Jupiter, 1891. *With Tables of the Inequalities.*

By A. Marth.

The selection of the plane of *Jupiter's* equator, in preference to that of the orbit, as the fundamental plane, to which the positions of the satellites are to be referred, offers upon examination such obvious advantages that it is not easy to understand why it has not been adopted long ago in all computations connected with the planet's system.

Let γ and Γ denote the inclination and node of the orbit of a satellite in reference to the adopted fundamental plane, v and l the satellite's true and mean longitude in the orbit, a its mean distance from the planet's centre, $r=a\rho$ its radius vector, v' and b its longitude and latitude in reference to the fundamental plane, L+180° and B the corresponding jovicentric longitude and latitude of the Earth, Δ its distance, $\Lambda+180°$, B and R the analogous coordinates of the Sun. Referring the position of the satellite to three rectangular axes passing through the planet's centre, of which the z axis is the prolongation of Δ, while the x axis is in the fundamental plane, the jovicentric rectangular and polar coordinates of the satellite are, if σ is the

angle between the radius vector and the s axis, and $p-P$ the position-angle of the radius vector reckoned from the direction of the y axis:

$$(x) = r \sin\sigma \sin(p-P) = r \cos b \sin(v'-L)$$
$$(y) = r \sin\sigma \cos(p-P) = r \cos b \cos(v'-L) \sin B + r \sin b \cos B$$
$$(z) = r \cos\sigma \qquad = r \cos b \cos(v'-L) \cos B - r \sin b \sin B.$$

But

$$\cos b \sin(v'-\Gamma) = \sin(v-\Gamma) \cos\gamma$$
$$\cos b \cos(v'-\Gamma) = \cos(v-\Gamma)$$
$$\sin b \qquad = \sin(v-\Gamma) \sin\gamma.$$

Hence

$$r \sin\sigma \sin(p-P) = r \sin(v-L) \qquad - r \sin b \,.\, \tan\tfrac{1}{2}\gamma \cos(L-\Gamma)$$
$$r \sin\sigma \cos(p-P) = r \cos(v-L) \sin B + r \sin b \cos B - r \sin b \,.\, \tan\tfrac{1}{2}\gamma \sin(L-\Gamma) \sin B$$
$$r \cos\sigma \qquad = r \cos(v-L) \cos B - r \sin b \sin B - r \sin b \,.\, \tan\tfrac{1}{2}\gamma \sin(L-\Gamma) \cos B.$$

The geocentric angle s between the satellite and the planet's centre and the linear distance Δ' of the satellite from the Earth are found by

$$\Delta' \sin s = r \sin\sigma$$
$$\Delta' \cos s = \Delta + r \cos\sigma.$$

If the plane of *Jupiter's* equator is made the fundamental plane, the last terms in the expressions of the coordinates are very small, and the geocentric coordinates become, as the term $\nu \sin b \sin B$ is not appreciable in Δ'

$$\Delta' = \Delta + a\rho \cos(v-L) \cos B$$
$$x'' = s \sin(p-P) = \frac{a''}{\Delta'} \,.\, \rho\,[\sin(v-L) - \sin(v-\Gamma) \sin\gamma \tan\tfrac{1}{2}\gamma \cos(L-\Gamma)]$$
$$y'' = s \cos(p-P) = \frac{a''}{\Delta'} \,.\, \rho\,[\cos(v-L) \sin B + \sin(v-\Gamma) \sin\gamma \cos B],$$

where

$$a'' = a\omega'' = \frac{a}{\text{arc } 1''},$$

and where the second term in the expression of x'' may be usually discarded, since at its maximum it does not amount to more than 0″·01 for Sat. II. and IV., and is quite insensible for Sat. I. and III.

By means of these formulæ accurate positions of the satellites may be readily computed if the data and tables required for the purpose are supplied; and the equations between observed and computed positions and the corresponding variations of the elements from which the data are derived may

also be easily formed. If rectangular coordinates, or differences of coordinates, parallel to the axes of *Jupiter's* disc, are measured, care ought to be taken that they are measured in the directions of the computed position-angles P+90° and P, and that the directions used should be properly read off and stated, so that any needed reductions may be duly applied. The equations for rectangular coordinates are

$$\delta x'' = \frac{a}{\Delta'} \cdot \rho \cos (v - \mathrm{L})\, \delta v + x'' \cdot \frac{\delta r}{r}$$

$$\delta y'' = \frac{a}{\Delta'} \rho \left[-\sin (v - \mathrm{L}) \sin \mathrm{B} + \cos (v - \Gamma) \sin \gamma \cos \mathrm{B} \right] \delta v$$

$$+ \frac{a}{\Delta'} \rho \cos \mathrm{B} \cdot \sin v . \delta (\gamma c)$$

$$+ \frac{a}{\Delta'} \rho \cos \mathrm{B} \cdot \cos v . \delta (\gamma s)$$

$$+ y'' \cdot \frac{\delta r}{r},$$

where γc is written for $\gamma \cos (\mathrm{O} - \Gamma)$, and γs for $\gamma \sin (\mathrm{O} - \Gamma)$, O being the point from which the longitudes are reckoned. The variation δv represents the variations of the mean longitude δl and of the chief inequalities on which the determination of the masses of the satellites and of the eccentricities of their orbits depends, and must be considered specially for each satellite.

If, instead of the rectangular coordinates x'' and y'', the polar coordinates s and p are furnished by the measurements, the equations between the observed and computed positions and the variations of the elements become

$$\delta s = \frac{a}{\Delta'} \rho \cos \mathrm{B} \left[\sin (p - \mathrm{P}) \cos \sigma + \cos (p - \mathrm{P}) \cos (v - \Gamma) \sin \gamma \right] . \delta v$$

$$+ \frac{a}{\Delta'} \rho \cos \mathrm{B} \cdot \frac{\cos (p - \mathrm{P})}{\sin \sigma} \cdot \sin v . \delta (\gamma c)$$

$$+ \frac{a}{\Delta'} \rho \cos \mathrm{B} \cdot \frac{\cos (p - \mathrm{P})}{\sin \sigma} \cdot \cos v . \delta (\gamma s)$$

$$+ s \cdot \frac{\delta r}{r}$$

$$s \delta p = \frac{a}{\Delta'} \rho \cdot \frac{\sin \mathrm{B} + \sin \gamma \sin (\mathrm{L} - \Gamma) \cos \mathrm{B}}{\sin \sigma} \cdot \delta v$$

$$- \frac{a}{\Delta'} \rho \cos \mathrm{B} \cdot \sin (p - \mathrm{P}) \cdot \sin v . \delta (\gamma c)$$

$$- \frac{a}{\Delta'} \rho \cos \mathrm{B} \cdot \sin (p - \mathrm{P}) \cdot \cos v . \delta (\gamma s).$$

With the requisite modifications, the equations are also applicable for the computation of the transits of the satellites across the planet's disc and of their occultations by the disc.

The substitution of the coordinates of the Sun for those of

the Earth gives the equations of the jovicentric coordinates of the satellite referred to the axis of the shadow-cone of *Jupiter* as the z axis.

$$r \sin \sigma \sin \pi = a\rho \sin (v-\Lambda) \qquad -a\rho \sin (v-\Gamma) \,.\, \sin \gamma \tan \tfrac{1}{2}\gamma \cos (\Lambda-\Gamma)$$

$$r \sin \sigma \cos \pi = a\rho \cos (v-\Lambda) \sin B + a\rho \sin (v-\Gamma) \,.\, \sin \gamma \cos B$$

$$r \cos \sigma \qquad = a\rho \cos (v-\Lambda) \cos B - a\rho \sin (v-\Gamma) \,.\, \sin \gamma \sin B,$$

where π is the position-angle of r reckoned from the y axis.

The distance $r \sin \sigma$ of the satellite from the axis of the shadow-cone must then be compared with the corresponding radius of the section of the shadow which passes through the point $r \cos \sigma$ of the z axis, or rather with the corresponding radii of the three cones, of which one has its point in the centre of the Sun and envelopes *Jupiter's* spheroid, while the others are the two edge-cones which envelope the Sun and *Jupiter*, and which represent the geometrical outline of the umbra and penumbra. However, as it seems desirable to illustrate some further remarks by a practical application to observed eclipses, I postpone these remarks on eclipses, and also on transits of the shadows of satellites across the planet's disc, till I shall have had the opportunity of computing some of the eclipses, which, it is to be expected, will be observed photometrically as well as in the usual way during the present apparition of *Jupiter*.

The question what values of the elements of the orbits and of the inequalities are available, which approach so near to the true ones that they may be confidently adopted in the computations, is beset with considerable doubt. Our present knowledge of *Jupiter's* system is in a curiously unsatisfactory state. While almost all other branches of astronomical science have made great progress during the last half-century, while especially the orbits of all the other satellites have become better known, there has been practically no growth in our knowledge of the motions of the satellites of *Jupiter*. The cause of this backwardness can be traced clearly enough, and it is high time that it should be pointed out unreservedly, so that it may at last be got rid of. The chief obstacle in the way of progress has been the mistaken notion that the predictions of the times of the eclipses must be made by means of special eclipse tables, and that for the purpose of continuing these predictions it is necessary to construct continuations of such tables. None of the offices at which the predictions are computed has ventured to leave the narrow artificial track prescribed by Damoiseau's tables, and to follow instead an independent course, the adoption of which, while readily allowing any degree of attainable accuracy in the predictions of the times of eclipses and other phenomena, would also have provided the means for computing accurate places of the satellites, and for rendering the results of the observations available for correcting the assumed elements and other constants. In consequence of such means not having been furnished in any

of the ephemerides, the great mass of observations of the satellites made during the last half-century has hitherto remained uncomputed, and has not yet been made contributory to our better knowledge of *Jupiter's* system. Moreover, the results deduced by Delambre and Damoiseau from preceding observations of eclipses have had to be accepted simply upon trust, for the evidence upon which they are founded is unknown. Delambre's statement on page iv of his "Tables Ecliptiques des Satellites de *Jupiter*," Paris, 1817, "Si je ne puis espérer de faire moi-même ces améliorations, je tâcherai du moins de laisser les matériaux dans un ordre assez clair et assez commode pour que le travail puisse être continué sans qu'on soit obligé de recommencer les calculs des anciennes éclipses, . . ." leaves room for hope that there may still exist some MS. of his which might throw considerable light upon his labours, and a search for which might not be fruitless. The regret, which Bessel expressed, 1842 (*Astron. Untersuchungen*, vol. ii. pp. 27 and 25) respecting the insufficiency of the information to be found in the introduction of Damoiseau's tables and his apprehension of the consequences have been only too well justified. There exists a MS. of Damoiseau in explanation of his tables, which Professor Souillart has had at his service; but it does not seem to throw any light upon some deficiencies or inconsistencies in Damoiseau's statements, which require to be cleared up.

I have long been desirous to extend the ephemerides for physical observations of *Jupiter*, which I have given since 1872 (the first ones for the oppositions of 1872–74 anonymously in the *Astron. Register*, the following ones since the opposition of 1875 in the *Monthly Notices*), so as to make them available for computing the positions of the satellites; but want of time and also the expectation that better materials to work with than Damoiseau's would be accessible before long prevented my doing so. The incidental statement by Professor Darwin (*Monthly Notices*, vol. 37, p. 81, footnote ‡) of the masses of the satellites which Professor Adams had determined, and which indicated that he was at work on the whole problem, induced me to postpone further proceedings, and to give merely the values of the inclinations and nodes of the orbits referred to *Jupiter*'s equator. Meanwhile Professor Souillart's interesting investigations have been published in vol. 45 of the *Memoirs of the Royal Astronomical Society*, and in vol. 30 of the *Mémoires présentés par divers savants à l'Académie des Sciences de l'Institut de France*. If the adoption of Professor Souillart's final values of the inequalities of the motions of the satellites and of the variations of the elements, as given on pp. 180 to 193 of the latter publication is not free from doubts and misgivings, it is chiefly because they are founded upon Damoiseau's data, which are not sufficiently trustworthy for the purpose. As an instance, I may mention the doubt concerning the mass of the fourth satellite. The determination of this mass depends greatly on the determination

of the coefficient of sin $(l_3 - \varpi_4)$ (the angle between the mean longitude of Sat. III. and the apse of Sat. IV.), an inequality in the motion of the third satellite. Delambre finds from observation the value of this coefficient $116^s{\cdot}76$ from which Laplace deduces the mass of Sat. IV. Damoiseau reduces the coefficient from $116^s{\cdot}76$ to $65^\circ{\cdot}073$, but alters the mass of Sat. IV. only slightly. His values of the coefficient and of the mass are inconsistent with each other. Professor Adams appears to have satisfied himself that Damoiseau's coefficient is right, and that consequently his mass of Sat. IV. is wrong, and he reduces the mass accordingly by about one-half. Professor Souillart, on the other hand, assumes the correctness of Damoiseau's mass and deduces a coefficient approaching that of Delambre. The question, which is the correct coefficient and the correct mass, can only be decided by an extended discussion of the observations. The discrepancies between the coefficients of the chief inequalities, as determined by Souillart and by Damoiseau from approximately the same elements, are so considerable that it is clear that their true values must first be trustworthily deduced from the observations before a refined theory can be securely built upon them.

The values of P, L, B, Λ, *B*, which are required for the application of the formulæ for computing the positions of the satellites, are already published in the "Ephemeris for Physical Observations of *Jupiter*," in the present volume of the *Monthly Notices*, p. 360 ff. The adopted fundamental plane depends on Souillart's assumed node and inclination for 1850, and on his values of the shifting of the equator on the orbit (found on p. 157 of the second Memoir), but with the substitution of the precession adopted by Le Verrier for that of Delambre.

The longitude of the node and the inclination of the fundamental plane in reference to the movable plane of *Jupiter's* orbit, as given in Le Verrier's Tables, are—

	Node Ω.	Inclination.
1880 Apr. 14	135° 10′ 13″·24	3° 4′ 4″·27
1890 Feb. 21	135 18 0·83	4·51
1900 Jan. 0	135 25 48·43	3 4 4·75

and in reference to the ecliptic—

	Long. of Node.	Inclination.	Long. of Ω.
1880 Apr. 14	336° 6′ 15″·55	2° 8′ 57″·11	135° 11′ 27″·31
1890 Feb. 21	336 13 51·99	2 9 0·53	135 19 14·93
1900 Jan. 0	336 21 28·39	2 9 3·94	135 27 2·55

The values of the node N, the inclination I, and the longitude of Ω (or N+NΩ), referred to the plane parallel to the

Earth's true equator, which have served for the computation of P, L—O, and B, are—

	N.	I.	N+NO.
1891 Apr. 17	−2°·0169	25°·4364	135°·1508
May 17	2·0169	·4363	·1519
June 16	2·0168	·4363	·1533
July 16	2·0166	·4365	·1548
Aug. 15	2·0165	·4367	·1560
Sept. 14	−2·0164	25·4368	135·1570
Oct. 14	2·0164	·4369	·1578
Nov. 13	2·0163	·4368	·1588
Dec. 13	2·0162	·4368	·1602
1892 Jan. 12	2·0161	·4369	·1617
Feb. 11	−2·0160	25·4371	135·1630

As the mean and true longitudes l and v and the longitudes ϖ of the lower apses of the orbits of the different satellites are here distinguished by having the number of the satellite attached (as in Delambre's and Damoiseau's Tables), it will be useful to state expressly the corresponding notation of Professor Souillart.

$l_1\ l_2\ l_3\ l_4 = l\ l'\ l''\ l'''$ of Souillart

$v_1\ v_2\ v_3\ v_4 = v\ v'\ v''\ v'''$ „

$\varpi_1 = g\,t + \beta$ $\qquad$ $G_1 = b_4 t + \gamma_4 - b\,t - \gamma$ of Souillart

$\varpi_2 = g_1 t + \beta_1$ $\qquad$ $G_2 = b_4 t + \gamma_4 - b_1 t - \gamma_1$

$\varpi_3 = g_2 t + \beta_2$ $\qquad$ $G_3 = b_4 t + \gamma_4 - b_2 t - \gamma_2$

$\varpi_4 = g_3 t + \beta_3$ $\qquad$ $G_4 = b_4 t + \gamma_4 - b_3 t - \gamma_3$

The values of $\varpi - O$ and of G adopted in the preparation of the tabular data are the following:

	$\varpi_1 - O$.	$\varpi_2 - O$.	$\varpi_3 - O$.	$\varpi_4 - O$.
1891 Apr. 17	210°·5295	38°·2069	204°·2501	146°·4513
June 16	219·4845	40·8208	204·6819	146·5690
Aug. 15	228·4394	43·4348	205·1138	146·6868
Oct. 14	237·3944	46·0487	205·5456	146·8046
Dec. 13	246·3494	48·6626	205·9774	146·9224
1892 Feb. 11	255·3043	51·2765	206·4093	147·0401

	G_1	G_2	G_3	G_4
1891 Apr. 17	126°92	295°1469	322°4955	303°5860
June 16	135·39	297·1275	322·9166	303·6999
Aug. 15	143·86	299·1081	323·3378	303·8138
Oct. 14	152·32	301·0887	323·7589	303·9278
Dec. 13	160·79	303·0693	324·1801	304·0417
1892 Feb. 11	169·25	305·0498	324·6012	304·1556

The mean longitudes $l-0$ of the satellites, given for Greenwich noon at intervals of ten days, have been so adjusted that, while the altered constant of the velocity of light is allowed for, and also some plausible corrections have been adopted, the corrected values for the epoch 1750 have been only slightly altered. The resulting mean daily motions

of l_1-0 are	203°4889560
l_2-0	101·3747256
l_3-0	50·3176104
l_4-0	21·5710740

The columns headed S_1, S_2, S_3, S_4 contain the sums of all the inequalities in longitude, which are independent of the longitudes of the satellites, and consist of the following terms, the coefficients of which are those of Professor Souillart:

Coefficients of S_1	Coefficients of S_2	Coefficients of S_3	Coefficients of S_4	
+ 2″206	−36″617	−48″470	−115″012	× sin M
− 0·176	− 3·033	− 4·416	− 10·425	× sin W
...	− 0·336	− 0·475	− 1·122	× sin W_1
−35·839	−10·167	− 0·204	...	× sin G_2
...	− 5·682	− 8·509	+ 6·187	× sin G_3
+ 0·436	− 6·044	− 9·284	− 3·241	× sin G_4
− 9·459	− 3·929	− 1·677	...	× sin (G_2-G_3)
+ 3·536	− 1·541	− 4·072	− 3·150	× sin (G_3-G_4)
− 1·488	− 0·550	− 0·196	...	× sin (G_2-G_4)
− 1·320	+ 0·464	+ 2·388	− 2·886	× sin $(\varpi_3-\varpi_4)$

where M denotes the mean anomaly of *Jupiter*, and W and W_1 the values of $5l^{IV}-2l^{IV}-16°\ 38'$ and $l^{IV}-2l^{V}-1°\ 30'$ in the notation of Le Verrier's Tables.

Before explaining the arguments, the equations may be stated by which the values of γ and $O-\Gamma$, given at the bottom of the pages, have been computed. They are—

$$\gamma_1 \sin(O-\Gamma_1) = \quad'' - 33''.035 \sin G_2 - 3''.914 \sin G_3 + 1''.394 \sin G_4 - 0''.915 \sin V - 4''.803 \sin G_1$$

$$\gamma_1 \cos(O-\Gamma_1) = 7''.24 - 33''.035 \cos G_2 - 3''.914 \cos G_3 + 1''.394 \cos G_4 - 0''.915 \cos V - 4''.803 \cos G_1$$

$$\gamma_2 \sin(O-\Gamma_2) = \quad'' - 1689''.882 \sin G_2 - 102''.264 \sin G_3 - 15''.711 \sin G_4 - 2''.817 \sin V - 0''.372 \sin(V-G_2)$$

$$\gamma_2 \cos(O-\Gamma_2) = 64''.34 - 1689''.882 \cos G_2 - 102''.264 \cos G_3 - 15''.711 \cos G_4 - 2''.817 \sin V - 0''.372 \cos(V-G_2)$$

$$\gamma_3 \sin(O-\Gamma_3) = \quad'' + 57''.437 \sin G_2 - 644''.173 \sin G_3 - 97''.328 \sin G_4 - 6''.389 \sin V - 0''.368 \sin(V-G_3)$$

$$\gamma_3 \cos(O-\Gamma_3) = 295''.07 + 57''.437 \cos G_2 - 644''.173 \cos G_3 - 97''.328 \cos G_4 - 6''.389 \cos V - 0''.368 \cos(V-G_3)$$

$$\gamma_4 \sin(O-\Gamma_4) = \quad'' + 1''.546 \sin G_2 + 125''.267 \sin G_3 - 811''.414 \sin G_4 - 13''.694 \sin V - 1''.145 \sin(V-G_4)$$

$$\gamma_4 \cos(O-\Gamma_4) = 1449''.35 + 1''.546 \cos G_2 + 125''.267 \cos G_3 - 811''.414 \cos G_4 - 13''.694 \cos V - 1''.145 \cos(V-G_4),$$

where V is written for $2(O-A)$, and where the constants in the cos terms vary slightly, the correction for 1880 April 14 being $-0''.48$, and for 1900 0.

The arguments of the inequalities represent the following angles:

$\alpha_1 = 2(l_1 - l_2) = 4\beta_1$
$\beta_1 = l_2 - l_3 + 180°$
$\gamma_1 = l_1 - \varpi_1$
$\delta_1 = l_1 - \varpi_3$
$\epsilon_1 = l_2 - 2l_3 + \varpi_1 + 180°$
$\zeta_1 = l_2 - 2l_3 + \varpi_2$
$\eta_1 = l_2 - 2l_3 + \varpi_3$
$\theta_1 = l_2 - 2l_3 + \varpi_4$

$\alpha_2 = l_1 - l_2 = 2\beta_2$
$\beta_2 = l_2 - l_3 + 180° = \beta_1$
$\gamma_2 = l_2 - \varpi_2$
$\delta_2 = l_2 - \varpi_3$
$\epsilon_2 = l_2 - \varpi_4$
$\zeta_2 = l_2 - 2l_3 + \varpi_2 = \zeta_1$
$\eta_2 = l_2 - 2l_3 + \varpi_3 + 180°$
$\theta_2 = l_2 - 2l_3 + \varpi_4 + 180°$
$\iota_2 = l_2 - 2l_3 + \varpi_1 = \epsilon_1 + 180°$
$\kappa_2 = 2l_1 - 3l_2 + \varpi_3$
$\lambda_2 = 2l_1 - 3l_2 + \varpi_4$

$\alpha_3 = l_2 - \varpi_3$
$\beta_3 = l_3 - \varpi_4$
$\gamma_3 = l_2 - l_3 + 180° = \beta_1$
$\delta_3 = l_2 - l_4 + 180°$
$\epsilon_3 = 2l_2 - 3l_3 + \varpi_3 + 180°$
$\zeta_3 = l_2 - 2l_3 + \varpi_2$
$\eta_3 = l_2 - 2l_3 + \varpi_3$
$\theta_3 = l_2 - 2l_3 + \varpi_4$
$\iota_3 = l_3 - \varpi_2 + 180°$

$\alpha_4 = l_4 - \varpi_4$
$\beta_4 = l_3 - l_4 + 180° = \delta_3$
$\gamma_4 = l_4 - \varpi_3 + 180°$
$\delta_4 = l_4 - 2l_0 + \varpi_4$
$\epsilon_4 = 2(l_4 - l_0)$
$\zeta_4 = l_3 - 2l_4 + \varpi_4$
$\eta_4 = l_2 - l_4$
$\theta_4 = l_2 - 2l_4 + \varpi_3 + 180°$

l_0 in δ_4 and ϵ_4 denotes the heliocentric mean longitude of $\mathcal{U}$, reckoned from O.

These arguments are expressed in parts of the circumference of the circle.

For each satellite are then given the motions of the longitudes and of the arguments for every six hours of the interval of ten days, and for every ten minutes of the interval of six hours.

The arguments furnish then the equivalents of the inequalities, which are composed as follows:

First Satellite.

Radius Vector.	Arg.	Longitude.	Arg.
$\rho_1 =$ 1·0000 096		$v_1 = l_1 +$ 1554″·759 sin α_1	
− ·0037 751 cos α_1	α_1	+ 5·029 sin $2\alpha_1$	α_1
− 119 cos $2\alpha_1$		+ 12·357 sin $2\beta_1$	
− ·0000 607		− 6·268 sin $3\beta_1$	β_1
− ·0000 173 cos $2\beta_1$		+ 8·796 sin γ_1	γ_1
+ 121 cos $3\beta_1$	β_1	+ 8·145 sin δ_1	δ_1
+ 294		+ 11·000 sin ϵ_1	ϵ_1
− 213 cos γ_1	γ_1	+ 23·041 sin ζ_1	ζ_1
+ 213		+ 19·689 sin η_1	η_1
− 196 cos δ_1	δ_1	+ 10·179 sin θ_1	θ_1
+ 196			

Second Satellite.

Radius Vector.	Arg.	Longitude.	Arg.
$\rho_2 =$ 1·0000 421		$v_2 = l_2 +$ 3692″·981 sin α_2	
− ·0090 095 cos α_2		+ 22·434 sin $2\alpha_2$	α_2
− 456 cos $2\alpha_2$	α_2	+ 1·491 sin $3\alpha_2$	
+ 062 cos $3\alpha_2$		+ 48·578 sin β_2	
− ·0005 060		− 20·498 sin $2\beta_2$	β_2
− ·0000 672 cos β_2		− 1·505 sin $3\beta_2$	
+ 634 cos $2\beta_2$		+ 45·246 sin γ_2	γ_2
+ 061 cos $3\beta_2$	β_2	+ 79·680 sin δ_2	δ_2
+ ·0000 770		+ 42·593 sin ϵ_2	ϵ_2
− ·000 1096 cos γ_2	γ_2	+ 95·284 sin ζ_2	ζ_2
+ 1096		+ 120·671 sin η_2	η_2
− ·000 1931 cos δ_2	δ_2	+ 62·966 sin θ_2	θ_2
+ 1931		+ 6·609 sin ι_2	ι_2
− ·000 1032 cos ϵ_2	ϵ_2	+ 6·947 sin κ_2	κ_2
+ 1032		+ 3·624 sin λ_2	λ_2
− ·000 0152 cos κ_2	κ_2		
+ 152			
− ·000 0079 cos λ_2	λ_2		
+ 79			

Third Satellite.

Radius Vector.		Longitude.	
$\rho_3 =$ 1·0000 009	Arg.	$v_3 = l_3 +$ 462″·880 sin α_3	Arg.
− ·0011 219 cos α_3	α_3	+ (0·324 sin $2\alpha_3$)	α_3
− 010 cos $2\alpha_3$		+ 241·905 sin β_3	β_3
− ·0013 050		+ (0·339 sin $2\beta_3$)	
− ·0005 864 cos β_3	β_3	+ 228·473 sin γ_3	γ_3
− 008 cos $2\beta_3$		− 4·084 sin $2\gamma_3$	
+ ·0005 872		+ 2·097 sin $3\gamma_3$	
− ·0005 827 cos γ_3	γ_3	− 0·286 sin $4\gamma_3$	
+ 155 cos $2\gamma_3$		+ 14·620 sin δ_3	δ_3
+ 024 cos $3\gamma_3$		+ 49·710 sin $2\delta_3$	
+ 014 cos $4\gamma_3$		− 3·503 sin $3\delta_3$	
+ ·0005 634		+ 0·814 sin $4\delta_3$	
− ·0000 221 cos δ_3	δ_3	− 0·258 sin $5\delta_3$	
− ·0001 320 cos $2\delta_3$		+ 2·012 sin ϵ_3	ϵ_3
+ 117 cos $3\delta_3$		+ 15·816 sin ζ_3	ζ_3
− 031 cos $4\delta_3$		+ 23·602 sin η_3	η_3
+ 011 cos $5\delta_3$		+ 12·062 sin θ_3	θ_3
+ ·0001 444		+ 1·936 sin ι_3	ι_3
− ·0000 050 cos ϵ_3	ϵ_3		
+ 50			
− ·0000 050 cos ι_3	ι_3		
+ 050			

For the sake of proper arrangement, the small second terms of the inequalities in longitude depending on α_3 and β_3 have been omitted and the columns transferred.

Fourth Satellite.

Radius Vector.		Longitude.	
$\rho_4 =$ 1·0000 265	Arg.	$v_4 = l_4 +$ 2995″·688 sin α_4	Arg.
− ·0072 597 cos α_4	α_4	+ 13·592 sin $2\alpha_4$	α_4
− 264 cos $2\alpha_4$		+ 9·189 sin β_4	β_4
− ·0003 204		− 4·571 sin $2\beta_4$	
− ·0001 105 cos β_4	β_4	+ 0·951 sin $3\beta_4$	
+ 201 cos $2\beta_4$		+ 59·063 sin γ_4	γ_4
− 047 cos $3\beta_4$		+ 22·527 sin δ_4	δ_4
+ ·0000 951		+ 2·208 sin ϵ_4	ϵ_4
− ·0001 431 cos γ_4	γ_4	+ 2·535 sin ζ_4	ζ_4
+ ·0001 431		+ 1·682 sin η_4	η_4

Fourth Satellite.

Radius Vector.

$$\rho_4 = \left.\begin{array}{l} -\ 0000\ 547 \cos \delta_4 \\ +\ 547 \end{array}\right\} \delta_4$$

$$\left.\begin{array}{l} -\ 0000\ 148 \cos \epsilon_4 \\ +\ 148 \end{array}\right\} \epsilon_4$$

$$\left.\begin{array}{l} -\ 0000\ 043 \cos \zeta_4 \\ +\ 043 \end{array}\right\} \zeta_4$$

$$\left.\begin{array}{l} +\ 0000\ 084 \cos \eta_4 \\ +\ 084 \end{array}\right\} \eta_4$$

Longitude.

$$v_4 = l_4 + \ 1''{\cdot}688 \sin \theta_4 \quad \text{Arg. } \theta_4$$

The inequalities of the radius vector, which Professor Souillart expresses in semi-diameters of *Jupiter's* equator, have been converted into those of the mean distance as unit by employing the values given on p. 10 of his Memoir.

The values of log a and log a'', corresponding to various values of the reciprocal of the mass of *Jupiter's* system, are—

	Sat. I.		*Sat. II.*	
$\frac{\text{Mass of Sun}}{\text{Mass of Jupiter}}$	log a_1	log a_1''	log a_2	log a_2''
1047·0	7·450 202	2·764 627	7·651 885	2·966 310
7·1	188	613	871	296
7·2	174	599	857	282
7·3	160	586	843	268
7·4	147	572	829	254
7·5	133	558	815	241
7·6	119	544	802	227
1047·7	7·450 105	2·764 530	7·651 788	2·966 213
7·8	092	517	794	199
7·9	078	503	760	185
8·0	064	489	746	171
8·1	050	475	733	158
8·2	036	461	719	144
8·3	022	447	705	130
1048·4	7·450 009	2·764 434	7·651 691	2·966 116

	Sat. III.		*Sat. IV.*	
$\frac{\text{Mass of Sun}}{\text{Mass of Jupiter}}$	log a_3	log a_3''	log a_4	log a_4''
1047·0	7·854 676	3·169 102	8·099 892	3·414 317
7·1	663	088	878	304
7·2	649	074	865	290
7·3	635	060	851	276
7·4	621	046	837	262
7·5	607	032	823	248
7·6	593	019	809	234

Mass of Sun / Mass of Jupiter	*Sat. III.* log a_3	log a_3''	*Sat. IV.* log a_4	log a_4''
1047·7	7·854 580	3·169 005	8·099 795	3·414 221
7·8	566	3·168 991	782	207
7·9	552	977	768	193
8·0	538	963	754	179
8·1	524	949	740	165
8·2	511	936	726	152
8·3	497	922	713	138
1048·4	7·854 483	3·168 908	8·099 699	3·414 124

The inequalities of the radius vector are given to the sixth decimal of the mean distance as unit, while those of the longitude are given to the fourth decimal of a degree. In order to estimate the accuracy with which the computations have to be made in order to attain the degree of accuracy in the results which may be desired, it is to be considered that a geocentric arc of $0''{\cdot}01$ corresponds for the distances represented by $\log \Delta = 0{\cdot}6$ and $0{\cdot}7$ at the conjunctions to a jovicentric arc of

	Sat. I.	*Sat. II.*	*Sat. III.*	*Sat. IV.*
$\log \Delta = 0{\cdot}6$	$14''{\cdot}12$	$8''{\cdot}87$	$5''{\cdot}56$	$3''{\cdot}16$
$0{\cdot}7$	$17{\cdot}78$	$11{\cdot}18$	$7{\cdot}00$	$3{\cdot}98$

or of

$\log \Delta = 0{\cdot}6$	$0^\circ{\cdot}0039$	$0^\circ{\cdot}0025$	$0^\circ{\cdot}0015$	$0^\circ{\cdot}0009$
$0{\cdot}7$	49	31	19	14

and at the greatest elongation to an inequality of ρ of

$\log \Delta = 0{\cdot}6$	·000069	·000041	·000028	·000015
$0{\cdot}7$	85	53	35	18

while the jovicentric motion of the satellite in one second of time is

$8''{\cdot}5$ $4''{\cdot}2$ $2''{\cdot}1$ $0''{\cdot}9$.

The inequalities of ρ have all been made positive by the addition of constants, the sum of which has been subtracted from the first term depending on the argument a. If the smaller inequalities are to be neglected, the added constants ought to be added to the first term of ρ.

The inequalities in longitude have the upper or lower sign according as the argument is between ·000 and ·500 or between ·500 and ·000. It will be remarked that the arguments are so chosen that, with the exception of portions of the inequalities depending on β_1, β_2, and δ_3, the inequalities are positive when the argument is to the left, and negative when it is to the right.

First Satellite.

Greenwich Noon.	Longitude. $l_1 - O$	δ_1	Arguments. α_1	β_1	γ_1	δ_1	ϵ_1
1891.	°	°					
Apr. 17	192·1279	+·0095	·2206	·305	·949	·966	·272
27	67·0175	95	·8936	·723	·597	·619	·296
May 7	301·9070	94	·5666	·142	·246	·271	·321
17	176·7966	94	·2396	·560	·894	·923	·346
27	51·6862	94	·9126	·978	·542	·575	·370
June 6	286·5757	93	·5857	·396	·191	·228	·395
16	161·4653	+·0093	·2587	·815	·839	·880	·420
26	36·3548	93	·9317	·233	·487	·532	·445
July 6	271·2444	92	·6047	·651	·135	·184	·469
16	146·1340	92	·2777	·069	·784	·837	·494
26	21·0235	92	·9507	·488	·432	·489	·519
Aug. 5	255·9131	91	·6237	·906	·080	·141	·543
15	130·8026	+·0091	·2967	·324	·729	·794	·568
25	5·6922	91	·9698	·742	·377	·446	·593
Sept. 4	240·5818	90	·6428	·161	·025	·098	·617
14	115·4713	90	·3158	·579	·674	·750	·642
24	350·3609	90	·9888	·997	·322	·403	·667
Oct. 4	225·2504	89	·6618	·415	·970	·055	·691
14	100·1400	+·0089	·3348	·834	·619	·707	·716
24	335·0296	89	·0078	·252	·267	·359	·741
Nov. 3	209·9191	88	·6809	·670	·915	·012	·765
13	84·8087	88	·3539	·088	·564	·664	·790
23	319·6982	88	·0269	·507	·212	·316	·815
Dec. 3	194·5878	87	·6999	·925	·860	·969	·840
13	69·4774	+·0087	·3729	·343	·509	·621	·864
23	304·3669	86	·0459	·761	·157	273	·889
1892.							
Jan. 2	179·2565	86	·7189	·180	·805	·925	·914
12	54·1460	86	·3919	·598	·454	·578	·938
22	289·0356	85	·0650	·016	·102	·230	·963
Feb. 1	163·9252	85	·7380	·434	·750	·882	·988
11	38·8147	+·0085	·4110	·853	·399	·534	·012

	Inclination. γ_1	Node. $O - \Gamma_1$		Inclination. γ_1	Node. $O - \Gamma_1$
	°	°		°	°
1891 Apr. 17	0·0079	106·9	1891, Sept. 14	70·0080	108·8
May 17	79	107·3	Oct. 14	81	109·2
June 16	80	107·6	Nov. 13	81	109·6
July 16	80	108·0	Dec. 13	81	110·1
Aug. 15	80	108·4	Jan. 12	82	110·6
Sept. 14	0·0080	108·8	Feb. 11	0·0082	111·1

Greenwich Noon.	*First Satellite.* Arguments. ζ_1	η_1	θ_1	*Second Satellite.* Longitude. l_2-0	S_2	Arguments. α_2	β_2
1891.				°	°		
Apr. 17	·293	·754	·594	152·4208	+·0109	·61030	·305
27	·315	·775	·614	86·1680	·0108	·44680	·723
May 7	·337	·796	·635	19·9153	·0106	·28331	·142
17	·358	·816	·656	313·6626	·0105	·11982	·560
27	·380	·837	·676	247·4098	·0103	·95632	·978
June 6	·402	·858	·697	181·1571	·0102	·79283	·396
16	·424	·879	·717	114·9043	+·0101	·62934	·815
26	·445	·899	·738	48·6516	·0099	·46584	·233
July 6	·467	·920	·759	342·3988	98	·30235	·651
16	·489	·941	·779	276·1461	97	·13886	·069
26	·511	·962	·800	209·8934	95	·97536	·488
Aug. 5	·532	·982	·820	143·6406	94	·81187	·906
15	·554	·003	·841	77·3879	+·0092	·64837	·324
25	·576	·024	·861	11·1351	91	·48488	·742
Sept. 4	·598	·045	·882	304·8824	89	·32139	·161
14	·619	·065	·903	238·6296	88	·15789	·579
24	·641	·086	·923	172·3769	86	·99440	·997
Oct. 4	·663	·107	·944	106·1241	85	·83091	·415
14	·685	·128	·964	39·8714	+·0083	·66741	·834
24	·706	·148	·985	333·6187	82	·50392	·252
Nov. 3	·728	·169	·006	267·3659	80	·34043	·670
13	·750	·190	·026	201·1132	79	·17693	·088
23	·772	·211	·047	134·8604	77	·01344	·507
Dec. 3	·793	·231	·067	68·6077	76	·84994	·925
13	·815	·252	·088	2·3549	+·0074	·68645	343
23	·837	·273	·109	296·1022	72	·52296	·761
1892.							
Jan. 2	·859	·294	·129	229·8494	71	·35946	·180
12	·880	·314	·150	163·5967	69	·19597	·598
22	·902	·335	·170	97·3440	68	·03248	·016
Feb. 1	·924	·356	·191	31·0912	66	·86898	·434
11	·946	·377	·212	324·8385	+·0064	·70549	·853

	Inclination. γ_2	Node. $\Omega-\Gamma_2$	
1891.	°	°	
Apr. 17	0·4919	116·82	95
May 17	·4919	117·77	94
June 16	·4918	118·71	95
July 16	·4918	119·66	95
Aug. 15	·4917	120·61	95
Sept. 14	·4916	121·56	

Second Satellite.

Greenwich Noon. 1891.	Arguments. γ_2	δ_2	ϵ_2	ζ_2	η_2	θ_2	ι_2	κ_2	λ_2
April 17	·317	·856	·017	·293	·254	·094	·772	·365	·204
27	·132	·672	·832	·315	·275	·114	·796	·222	·061
May 7	·947	·488	·648	·337	·296	·135	·821	·079	·918
17	·762	·303	·464	·358	·316	·156	·846	·936	·775
27	·576	·119	·280	·380	·337	·176	·870	·794	·632
June 6	·391	·935	·096	·402	·358	·197	·895	·651	·490
16	·206	·751	·912	·424	·379	·217	·920	·508	·347
26	·021	·566	·728	·445	·399	·238	·945	·365	·204
July 6	·835	·382	·544	·467	·420	·259	·969	·223	·061
16	·650	·198	·360	·489	·441	·279	·994	·080	·918
26	·465	·014	·176	·511	·462	·300	·019	·937	·775
Aug. 5	·280	·829	·992	·532	·482	·320	·043	·794	·632
15	·094	·645	·808	·554	·503	·341	·068	·652	·489
25	·909	·461	·623	·576	·524	·361	·093	·509	·346
Sept. 4	·724	·277	·439	·598	·545	·382	·117	·366	·203
14	·539	·093	·255	·619	·565	·403	·142	·223	·061
24	·353	·908	·071	·641	·586	·423	·167	·081	·918
Oct. 4	·168	·724	·887	·663	·607	·444	·191	·938	·775
14	·983	·540	·703	·685	·628	·464	·216	·795	·632
24	·798	·356	·519	·706	·648	·485	·241	·652	·489
Nov. 3	·612	·171	·335	·728	·669	·506	·265	·510	·346
13	·427	·987	·151	·750	·690	·526	·290	·367	·203
23	·242	·803	·967	·772	·711	·547	·315	·224	·060
Dec. 3	·057	·619	·783	·793	·731	·567	·340	·081	·917
13	·871	·434	·598	·815	·752	·588	·364	·939	·774
23	·686	·250	·414	·837	·773	·609	·389	·796	·632
1892.									
Jan. 2	·501	·066	·230	·859	·794	·629	·414	·653	·489
12	·316	·882	·046	·880	·814	·650	·438	·510	·346
22	·130	·697	·862	·902	·835	·670	·463	·368	·203
Feb. 1	·945	·513	·678	·924	·856	·691	·488	·225	·060
11	·760	·329	·494	·946	·877	·712	·512	·082	·917

		Inclination. γ_2	Node. $0-\Gamma_2$	
		°	°	
1891	Sept. 14	0·4916	121·56	95
	Oct. 14	·4915	122·51	94
	Nov. 13	·4914	123·45	95
	Dec. 13	·4912	124·40	95
1892	Jan. 12	·4911	125·35	95
	Feb. 11	0·4909	126·30	

Third Satellite.

Greenwich Noon.	Longitude. $l_3 - O$	S_3	Arguments. α_3	β_3	γ_3	δ_3	ϵ_3
1891.	°	°					
April 17	222·5672	+·0113	·0509	·2114	·3051	·388	·992
27	5·7433	·0111	·4484	·6092	·7234	·186	·431
May 7	148·9194	·0110	·8459	·0067	·1417	·985	·870
17	292·0955	·0108	·2434	·4044	·5599	·783	·308
27	75·2716	·0106	·6409	·8021	·9782	·582	·747
June 6	218·4477	·0105	·0384	·1997	·3964	·380	·186
16	1·6239	+·0103	·4360	·5974	·8147	·179	·625
26	144·8000	·0101	·8335	·9950	·2329	·977	·064
July 6	287·9761	·0100	·2310	·3927	·6512	·776	·502
16	71·1522	·0098	·6285	·7903	·0694	·575	·941
26	214·3283	96	·0260	·1880	·4877	·373	·380
Aug. 5	357·5044	94	·4235	·5857	·9059	·172	·819
15	140·6805	+0093	·8210	·9833	·3242	·970	·258
25	283·8566	91	·2185	·3810	·7424	·769	·696
Sept. 4	67·0327	89	·6160	·7786	·1607	·567	·135
14	210·2088	87	·0136	·1763	·5789	·366	·574
24	353·3849	85	·4111	·5739	·9972	·164	·013
Oct. 4	136·5610	84	·8086	·9716	·4155	·963	·452
14	279·7371	+·0082	·2061	·3693	·8337	·761	·890
24	62·9132	80	·6036	·7669	·2520	·560	·329
Nov. 3	206·0893	78	·0011	·1646	·6702	·358	·768
13	349·2654	76	·3986	·5622	·0885	·157	·207
23	132·4415	74	·7961	·9599	·5067	·955	·646
Dec. 3	275·6176	72	·1936	·3575	·9250	·754	·084
13	58·7937	+·0070	·5912	·7552	·3432	·552	·523
23	201·9698	68	·9887	·1529	·7615	·351	·962
1892.							
Jan. 2	345·1459	67	·3862	·5505	·1797	·149	·401
12	128·3220	65	·7837	·9482	·5980	·948	·840
22	271·4981	63	·1812	·3458	·0162	·746	·278
Feb. 1	54·6742	61	·5787	·7435	·4345	·545	·717
11	197·8503	+·0059	·9762	·1411	·8527	·343	·156

	Inclination. γ_3	Node. $O - \gamma_3$		Inclination. γ_3	Node. $O - \Gamma_3$
	°	°		°	°
1891 April 17	0·1371	120·41	1891 Sept. 14	0·1360	120·82
May 17	·1369	120·50	Oct. 14	·1357	120·90
June 16	·1367	120·58	Nov. 13	·1355	120·98
July 16	·1364	120·66	Dec. 13	·1352	121·06
Aug. 15	·1362	120·74	1892 Jan. 12	·1349	121·14
Sept. 14	0·1360	120·82	Feb. 11	0·1346	121·22

Greenwich Noon.	*Third Satellite.* Arguments. ζ_3	η_3	θ_3	i_3	*Fourth Satellite.* l_4-0	Longitude. S_4	Arg. α_4
1891.					°	°	
April 17	·293	·754	·594	·012	262·9352	+ ·0159	·32357
27	·315	·775	·614	·409	118·6459	·0155	·92271
May 7	·337	·796	·635	·805	334·3567	·0152	·52185
17	·358	·816	·656	·202	190·0674	·0148	·12099
27	·380	·837	·676	·598	45·7781	·0144	·72013
June 6	·402	·858	·697	·995	261·4889	·0140	·31928
16	·424	·879	·717	·391	117·1996	+ ·0137	·91842
26	·445	·899	·738	·788	332·9104	·0133	·51756
July 6	·467	·920	·759	·184	188·6211	·0129	·11670
16	·489	·941	·779	·581	44·3318	·0125	·71584
26	·511	·962	·800	·977	260·0426	·0121	·31499
Aug. 5	·532	·982	·820	·374	115·7533	·0117	·91413
15	·554	·003	·841	·770	331·4641	+ ·0113	·51327
25	·576	·024	·861	·167	187·1748	·0109	·11241
Sept. 4	·598	·045	·882	·563	42·8855	·0105	·71155
14	·619	·065	·903	·960	258·5963	·0100	·31070
24	·641	·086	·923	·356	114·3070	·0096	·90984
Oct. 4	·663	·107	·944	·753	330·0178	92	·50898
14	·685	·128	·964	·149	185·7285	+ ·0088	·10812
24	·706	·148	·985	·546	41·4392	84	·70726
Nov. 3	·728	·169	·006	·942	257·1500	79	·30641
13	·750	·190	·026	·339	112·8607	75	·90555
23	·772	·211	·047	·735	328·5715	71	·50469
Dec. 3	·793	·231	·067	·132	184·2822	66	·10383
13	·815	·252	·088	·528	39·9929	+ ·0062	·70297
23	·837	·273	·109	·925	255·7037	57	·30212
1892.							
Jan. 2	·859	·294	·129	·321	111·4144	53	·90126
12	·880	·314	·150	·718	327·1252	49	·50040
22	·902	·335	·170	·114	182·8359	44	·09954
Feb. 1	·924	·356	·191	·511	38·5466	40	·69868
11	·946	·377	·212	·907	254·2574	+ ·0035	·29783

	Inclination. γ_4	Node. $\Omega-\Gamma_4$
1891.	°	°
Apr. 17	0·3455	29·07
May 17	·3457	29·11
June 16	·3460	29·15
July 16	·3462	29·18
Aug. 15	·3465	29·20
Sept. 14	0·3468	29·22

Longitude and of Arguments.

		ζ_1	η_1	θ_1			l_1-0	α_1	β_1	γ_1, δ_1
d	h				h	m	°			
0	0	·000	·000	·000	0	0	0·0	·0008	·000	·000
	6	1	1	1		2	0·2826	·0008	0	1
	12	1	1	1		4	0·5652	·0016	0	2
	18	2	2	2		6	0·8479	·0024	1	2
1	0	·002	·002	·002		8	1·1305	·0032	1	3
	6	3	3	3	0	10	1·4131	·0039	·001	·004
	12	3	3	3		20	2·8262	·0079	2	·008
	18	4	4	4		30	4·2394	·0118	3	·012
2	0	·004	·004	·004		40	5·6525	·0158	4	·016
	6	5	5	5		50	7·0656	·0197	5	·020
	12	5	5	5	1	0	8·4787	·0236	·006	·024
	18	6	6	6		10	9·8918	·0276	7	·027
3	0	·007	·006	·006		20	11·3050	·0315	8	·031
	6	7	7	7		30	12·7181	·0355	9	·035
	12	8	7	7		40	14·1312	·0394	·010	·039
	18	8	8	8		50	15·5443	·0433	·011	·043
4	0	·009	·008	·008	2	0	16·9574	·0473	·012	·047
	6	·009	·009	·009		10	18·3705	·0512	·013	·051
	12	·010	·009	·009		20	19·7837	·0552	·014	·055
	18	·010	·010	·010		30	21·1968	·0591	·015	·059
5	0	·011	·010	·010		40	22·6099	·0630	·016	·063
	6	·011	·011	·011		50	24·0230	·0670	·017	·067
	12	·012	·011	·011	3	0	25·4361	·0709	·018	·071
	18	·013	·012	·012		10	26·8492	·0749	·019	·075
6	0	·013	·012	·012		20	28·2624	·0788	·020	·078
	6	0·14	·013	·013		30	29·6755	·0827	·021	·082
	12	·014	·013	·013		40	31·0886	·0867	·022	·086
	18	·015	·014	·014		50	32·5017	·0906	·023	·090
7	0	·015	·015	·014	4	0	33·9148	·0946	·024	·094
	6	·016	·015	·015		10	35·3279	·0985	·025	·098
	12	·016	·016	·015		20	36·7411	·1024	·026	·102
	18	·017	·016	·016		30	38·1542	·1064	·027	·106
8	0	·017	·017	·016		40	39·5673	·1103	·028	·110
	6	·018	·017	·017		50	40·9804	·1142	·029	·114
	12	·018	·018	·018	5	0	42·3935	·1182	·030	·118
	18	·019	·018	·018		10	43·8067	·1221	·031	·122
9	0	·020	·019	·019		20	45·2198	·1261	·032	·126
	6	·020	·019	·019		30	46·6329	·1300	·033	·129
	12	·021	·020	·020		40	48·0460	·1339	·033	·133
	18	·021	·020	·020		50	49·4591	·1379	·034	·137
10	0	·022	·021	·021	6	0	50·8722	·1418	·035	·141

First Satellite.—Motions of

d	h	l_1-0	α_1	β_1	γ_1	δ_1	ϵ_1
		°					
0	0	0·0	·0000	·000	·000	·000	·000
	6	50·8722	·1418	·035	·141	·141	1
	12	101·7445	·2837	·071	·282	·283	1
	18	152·6167	·4255	·106	·424	·424	2
1	0	203·4890	·5673	·142	·565	·565	·002
	6	254·3618	·7091	·177	·706	·707	3
	12	305·2334	·8510	·213	·847	·848	4
	18	356·1057	·9928	·248	·988	·989	4
2	0	46·9779	·1346	·284	·130	·130	·005
	6	97·8502	·2764	·319	·271	·272	6
	12	148·7224	·4183	·355	·412	·413	6
	18	199·5946	·5601	·390	·553	·554	7
3	0	250·4669	·7019	·425	·694	·696	·007
	6	301·3391	·8437	·461	·836	·837	8
	12	352·2113	·9856	·496	·977	·978	9
	18	43·0836	·1274	·532	·118	·120	9
4	0	93·9558	·2692	·567	·259	·261	·010
	6	144·8281	·4110	·603	·401	·402	·010
	12	195·7003	·5529	·638	·542	·544	·011
	18	246·5725	·6947	·674	·683	·685	·012
5	0	297·4448	·8365	·709	·824	·826	·012
	6	348·3170	·9783	·745	·965	·967	·013
	12	39·1893	·1202	·780	·107	·109	·014
	18	90·0615	·2620	·815	·248	·250	·014
6	0	140·9337	·4038	·851	·389	·391	·015
	6	191·8060	·5456	·886	·530	·533	·015
	12	242·6782	·6875	·922	·671	·674	·016
	18	293·5505	·8293	·957	·813	·815	·017
7	0	344·4227	·9711	·993	·954	·957	·017
	6	35·2949	·1129	·028	·095	·098	·018
	12	86·1672	·2548	·064	·236	·239	·019
	18	137·0394	·3966	·099	·377	·381	·019
8	0	187·9116	·5384	·135	·519	·522	·020
	6	238·7839	·6802	·170	·660	·663	·020
	12	289·6561	·8221	·206	·801	·804	·021
	18	340·5284	·9639	·241	·942	·946	·022
9	0	31·4006	·1057	·276	·083	·087	·022
	6	82·2728	·2475	·312	·225	·228	·023
	12	133·1451	·3894	·347	·366	·370	·023
	18	184·0173	·5312	·383	·507	·511	·024
10	0	234·8896	·6730	·418	·648	·652	·025

Longitude and of Arguments.

		ζ_1	η_1	θ_1			l_1-0	α_1	β_1	γ_1, δ_1
d	h				h	m	°			
0	0	·000	·000	·000	0	0	0·0	·0000	·000	·000
	6	1	1	1		2	0·2826	·0008	0	1
	12	1	1	1		4	0·5652	·0016	0	2
	18	2	2	2		6	0·8479	·0024	1	2
1	0	·002	·002	·002		8	1·1305	·0032	1	3
	6	3	3	3	0	10	1·4131	·0039	·001	·004
	12	3	3	3		20	2·8262	·0079	2	·008
	18	4	4	4		30	4·2394	·0118	3	·012
2	0	·004	·004	·004		40	5·6525	·0158	4	·016
	6	5	5	5		50	7·0656	·0197	5	·020
	12	5	5	5	1	0	8·4787	·0236	·006	·024
	18	6	6	6		10	9·8918	·0276	7	·027
3	0	·007	·006	·006		20	11·3050	·0315	8	·031
	6	7	7	7		30	12·7181	·0355	9	·035
	12	8	7	7		40	14·1312	·0394	·010	·039
	18	8	8	8		50	15·5443	·0433	·011	·043
4	0	·009	·008	·008	2	0	16·9574	·0473	·012	·047
	6	·009	·009	·009		10	18·3705	·0512	·013	·051
	12	·010	·009	·009		20	19·7837	·0552	·014	·055
	18	·010	·010	·010		30	21·1968	·0591	·015	·059
5	0	·011	·010	·010		40	22·6099	·0630	·016	·063
	6	·011	·011	·011		50	24·0230	·0670	·017	·067
	12	·012	·011	·011	3	0	25·4361	·0709	·018	·071
	18	·013	·012	·012		10	26·8492	·0749	·019	·075
6	0	·013	·012	·012		20	28·2624	·0788	·020	·078
	6	0·14	·013	·013		30	29·6755	·0827	·021	·082
	12	·014	·013	·013		40	31·0886	·0867	·022	·086
	18	·015	·014	·014		50	32·5017	·0906	·023	·090
7	0	·015	·015	·014	4	0	33·9148	·0946	·024	·094
	6	·016	·015	·015		10	35·3279	·0985	·025	·098
	12	·016	·016	·015		20	36·7411	·1024	·026	·102
	18	·017	·016	·016		30	38·1542	·1064	·027	·106
8	0	·017	·017	·016		40	39·5673	·1103	·028	·110
	6	·018	·017	·017		50	40·9804	·1142	·029	·114
	12	·018	·018	·018	5	0	42·3935	·1182	·030	·118
	18	·019	·018	·018		10	43·8067	·1221	·031	·122
9	0	·020	·019	·019		20	45·2198	·1261	·032	·126
	6	·020	·019	·019		30	46·6329	·1300	·033	·129
	12	·021	·020	·020		40	48·0460	·1339	·033	·133
	18	·021	·020	·020		50	49·4591	·1379	·034	·137
10	0	·022	·021	·021	6	0	50·8722	·1418	·035	·141

First Satellite.—Inequalities.

Arg.	Radius Vector. α_1		β_1	γ_1	δ_1	Longitude. α_1		β_1	Arg.
·000	0·996 152	8	024	000	000	± °·0000	273	± °·0000	·000
·010	6 160	22	24	0	0	·0273	272	01	·990
·020	6 182	38	24	0	0	·0545	269	02	·980
·030	6 220	52	24	0	0	·0814	267	03	·970
·040	6 272	67	23	1	1	·1081	262	05	·960
·050	0·996 339	82	·023	001	001	± ·1343	256	± ·0006	·950
·060	6 421	95	22	2	1	·1599	251	08	·940
·070	6 516	109	21	2	2	·1850	242	10	·930
·080	6 625	122	21	3	2	·2092	235	12	·920
·090	6 747	134	21	3	3	·2327	225	14	·910
·100	0·996 881	147	020	004	004	± ·2552	215	± ·0016	·900
·110	7 028	159	20	5	4	·2767	203	18	·890
·120	7 187	169	21	6	5	·2970	192	22	·880
·130	7 356	179	21	7	6	·3162	179	24	·870
·140	7 535	189	22	8	7	·3341	166	25	·860
·150	0·997 724	198	023	009	008	± ·3507	152	± ·0027	·850
·160	7 922	205	25	10	09	·3659	137	29	·840
·170	8 127	212	27	11	10	·3796	123	30	·830
·180	8 339	219	29	12	11	·3919	106	31	·820
·190	8 458	224	31	13	12	·4025	91	31	·810
·200	0·998 782	229	034	015	014	± ·4116	74	± ·0030	·800
·210	9 011	232	36	16	15	·4190	57	29	·790
·220	9 243	235	39	17	16	·4247	41	27	·780
·230	9 478	236	42	19	17	·4288	24	25	·770
·240	9 714	237	44	20	18	·4312	7	21	·760
·250	0·999 951	237	047	021	020	± ·4319	10	± ·0017	·750
·260	1·000 188	236	49	23	21	·4309	28	13	·740
·270	0 424	234	51	24	22	·4281	44	08	·730
·280	0 658	231	52	25	23	·4237	61	± ·0002	·720
·290	0 889	227	53	27	24	·4176	77	∓ ·0004	·710
·300	1·001 116	222	053	028	026	± ·4099	93	∓ ·0010	·700
·310	1 328	216	53	29	27	·4006	109	∓ 16	·690
·320	1 554	210	52	30	28	·3897	124	∓ 22	680
·330	1 764	203	51	32	29	·3773	139	∓ 28	·670
·340	1 967	195	49	33	30	·3634	153	∓ 33	·660
·350	1·002 162	186	046	034	031	± ·3481	167	∓ ·0038	·650
·360	2 348	176	43	35	32	·3314	180	∓ 42	·640
·370	2 524	166	40	36	33	·3134	192	∓ 46	·630
·380	2 690	156	36	37	34	·2942	203	∓ 48	·620
·390	2 846	144	32	38	35	·2739	214	∓ 49	·610
·400	1·002 990		028	039	035	± ·2525		∓ ·0049	·600

First Satellite.—Inequalities.

Arg.	Radius Vector. a_1		β_1	γ_1	δ_1	Longitude. a_1		β_1	Arg.
·400	1·002 990	132	028	039	035	± °·2525	224	∓ °·0049	·600
·410	3 122	119	24	39	36	·2301	232	∓ 48	·590
·420	3 241	107	19	40	37	·2069	241	∓ 46	·580
·430	3 348	93	15	41	37	·1828	248	∓ 43	·570
·440	3 441	79	12	41	38	·1580	254	∓ 39	·560
·450	1·003 520	65	008	042	038	± ·1326	259	∓ ·0034	·550
·460	3 585	51	5	42	39	·1067	263	∓ 28	·540
·470	3 636	37	3	42	39	·0804	266	∓ 22	·530
·480	3 673	22	1	42	39	·0538	269	∓ 15	·520
·490	3 695	7	0	43	39	·0269	269	∓ 08	·510
·500	1·003 702		000	043	039	± ·0000		∓ ·0000	·500

Longitude (continued).

Arg.		γ_1	δ_1	ϵ_1	ζ_1	η_1	θ_1	Arg.	
·000	·500	± °·0000	± 00	± 00	± 00	± 00	± 00	·500	·000
·010	·490	02	01	02	04	03	02	·510	·990
·020	·480	03	03	04	08	07	04	·520	·980
·030	·470	05	04	06	12	10	05	·530	·970
·040	·460	06	06	08	16	14	07	·540	·960
·050	·450	± ·0008	± 07	± 09	± 20	± 17	± 09	·550	·950
·060	·440	09	08	11	24	20	10	·560	·940
·070	·430	10	10	13	27	23	12	·570	·930
·080	·420	12	11	15	31	26	14	·580	·920
·090	·410	13	12	16	34	29	15	·590	·910
·100	·400	± ·0014	± 13	± 18	± 38	± 32	± 17	·600	·900
·110	·390	16	14	19	41	35	18	·610	·890
·120	·380	17	15	21	44	37	19	·620	·880
·130	·370	18	16	22	47	40	21	·630	·870
·140	·360	19	17	24	49	42	22	·640	·860
·150	·350	± ·0020	± 18	± 25	± 52	± 44	± 23	·650	·850
·160	·340	21	19	26	54	46	24	·660	·840
·170	·330	21	20	27	56	48	25	·670	·830
·180	·320	22	20	28	58	49	26	·680	·820
·190	·310	23	21	28	60	51	26	·690	·810
·200	·300	± ·0023	± 22	± 29	± 61	± 52	± 27	·700	·800
·210	·290	24	22	30	62	53	27	·710	·790
·220	·280	24	22	30	63	54	28	·720	·780
·230	·270	24	22	30	63	54	28	·730	·770
·240	·260	24	23	30	64	55	28	·740	·760
·250	·250	± ·0024	± 23	± 31	± 64	± 55	± 28	·750	·750

Second Satellite.—Motions of

d	h	l_2-0	α_2	β_2	γ_2, δ_2, e_2	ι_2	ε_2, λ_2
		°					
0	0	0·0	·00000	·000	·000	·000	·000
	6	25·3437	·07091	·035	·070	1	·071
	12	50·6874	·14183	·071	·141	1	·143
	18	76·0310	·21274	·106	·211	2	·214
1	0	101·3747	·28365	·142	·282	·002	·286
	6	126·7184	·35456	·177	·352	3	·357
	12	152·0621	·42548	·213	·422	4	·429
	18	177·4058	·49639	·248	·493	4	·500
2	0	202·7495	·56730	·284	·563	·005	·571
	6	228·0931	·63821	·319	·634	6	·643
	12	253·4368	·70913	·355	·704	6	·714
	18	278·7805	·78004	·390	·774	7	·786
3	0	304·1242	·85095	·425	·845	·007	·857
	6	329·4679	·92186	·461	·915	8	·929
	12	354·8115	·99278	·496	·986	9	·000
	18	20·1552	·06369	·532	·056	9	·071
4	0	45·4989	·13460	·567	·126	·010	·143
	6	70·8426	·20552	·603	·197	·010	·214
	12	96·1863	·27643	·638	·267	·011	·286
	18	121·5299	·34734	·674	·337	·012	·357
5	0	146·8736	·41825	·709	·408	·012	·429
	6	172·2173	·48917	·745	·478	·013	·500
	12	197·5610	·56008	·780	·549	·014	·571
	18	222·9047	·63099	·815	·619	·014	·643
6	0	248·2484	·70190	·851	·689	·015	·714
	6	273·5920	·77282	·886	·760	·015	·786
	12	298·9357	·84373	·922	·830	·016	·857
	18	324·2794	·91464	·957	·901	·017	·929
7	0	349·6231	·98555	·993	·971	·017	·000
	6	14·9668	·05647	·028	·041	·018	·072
	12	40·3104	·12738	·064	·112	·019	·143
	18	65·6541	·19829	·099	·182	·019	·214
8	0	90·9978	·26921	·135	·253	·020	·286
	6	116·3415	·34012	·170	·323	·020	·357
	12	141·6852	·41103	·206	·393	·021	·429
	18	167·0288	·48194	·241	·464	·021	·500
9	0	192·3725	·55286	·276	·534	·022	·572
	6	217·7162	·62377	·312	·605	·023	·643
	12	243·0599	·69468	·347	·675	·023	·714
	18	268·4036	·76559	·383	·745	·024	·786
10	0	293·7473	·83651	·418	·816	·025	·857

The motions of ζ_2, η_2, θ_2 are the same as those of ζ η, θ on p. 525.

Second Satellite.—Inequalities.

Arg.	Radius Vector. α_2		β_2	γ_2	δ_2	ϵ_2	κ_2	λ_2	Longitude. α_2		Arg.
·400	1·006 813		153	198	349	187	028	014	± 0·5974		·600
·410	7 124	311	161	202	356	190	28	15	·5444	530	·590
·420	7 406	282	169	206	362	194	29	15	·4893	551	·580
·430	7 658	252	177	209	368	197	29	15	·4324	569	·570
·440	7 877	219	183	212	373	199	29	15	·3737	587	·560
		187								600	
·450	1·008 064		189	214	377	201	030	015	± 0·3137		·550
·460	8 218	154	193	216	380	203	30	16	·2524	613	·540
·470	8 338	120	197	217	383	205	30	16	·1901	623	·530
·480	8 425	87	199	218	385	206	30	16	·1272	629	·520
·490	8 477	52	201	219	386	206	30	16	·0637	635	·510
		17								637	
·500	1·008494		202	219	386	206	030	016	± 0·0000		·500

Longitude (continued).

Arg.		β_2	γ_2	δ_2	ϵ_2	ζ_2	η_2	θ_2	ι_2	κ_2	λ_2	Arg.	
·00	·50	∓ ·0000	± ·0000	·0000	·0000	·0000	·0000	·0000	00	00	00	·50	·00
·01	·49	∓ 03	08	14	07	17	21	11	01	01	01	·51	·99
·02	·48	∓ 06	16	28	15	33	42	22	02	02	01	·52	·98
·03	·47	∓ 09	24	41	22	50	63	33	03	04	02	·53	·97
·04	·46	∓ 09	31	55	29	66	83	44	05	05	03	·54	·96
·05	·45	∓ ·0009	∓ ·0039	·0068	·0037	·0082	·0104	·0054	06	06	03	·55	·95
·06	·44	∓ 06	46	·0081	44	·0097	·0123	64	07	07	04	·56	·94
·07	·43	∓ 01	54	·0094	50	·0113	·0142	74	08	08	04	·57	·93
·08	·42	± 06	61	·0107	57	·0128	·0161	84	09	09	05	·58	·92
·09	·41	± 15	67	·0119	63	·0142	·0180	94	10	10	05	·59	·91
·10	·40	± ·0025	± ·0074	·0130	·0069	·0156	·0197	·0103	11	11	06	·60	·90
·11	·39	37	80	·0141	75	·0169	·0214	·0111	12	12	06	·61	·89
·12	·38	51	86	·0152	81	·0181	·0229	·0120	13	13	07	·62	·88
·13	·37	65	92	·0161	86	·0193	·0244	·0128	13	14	07	·63	·87
·14	·36	81	97	·0171	91	·0204	·0258	·0135	14	15	08	·64	·86
·15	·35	± ·0096	± ·0102	·0179	·0096	·0214	·0271	·0142	15	16	08	·65	·85
·16	·34	·0111	·0106	·0187	·0100	·0223	·0283	·0148	16	16	08	·66	·84
·17	·33	·0125	·0110	·0194	·0104	·0232	·0294	·0153	16	17	09	·67	·83
·18	·32	·0139	·0114	·0200	·0107	·0239	·0303	·0158	17	17	09	·68	·82
·19	·31	·0151	·0117	·0206	·0110	·0246	·0312	·0163	17	18	09	·69	·81
·20	·30	± ·0162	± ·0120	·0211	·0113	·0252	·0319	·0166	17	18	10	·70	·80
·21	·29	·0171	·0122	·0214	·0115	·0256	·0325	·0169	18	19	10	·71	·79
·22	·28	·0178	·0123	·0217	·0116	·0260	·0329	·0172	18	19	10	·72	·78
·23	·27	·0183	·0125	·0220	·0117	·0263	·0333	·0174	18	19	10	·73	·77
·24	·26	·0187	·0125	·0221	·0118	·0264	·0335	·0175	18	19	10	·74	·76
·25	·25	± ·0188	± ·0126	·0221	·0118	·0265	·0335	·0175	18	19	10	·75	·75

Second Satellite.—Inequalities.

Arg.	Radius Vector. α_2		β_2	γ_2	δ_2	ϵ_2	κ_2	λ_2	Longitude. α_2		Arg.
·000	0·990 487	18	079	000	000	000	000	000	± 0°·0000	653	·000
·010	0 505	54	79	00	00	00	0	0	·0653	650	·990
·020	0 559	90	77	01	02	01	0	0	·1303	644	·980
·030	0 649	125	75	02	03	02	0	0	·1947	637	·970
·040	0 774	160	72	03	06	03	0	0	·2584	626	·960
·050	0·990 934	195	068	005	009	005	001	000	± 0·3210	613	·950
·060	1 129	218	63	07	13	07	1	1	·3823	597	·940
·070	1 357	260	58	10	18	10	1	1	·4420	579	·930
·080	1 617	292	52	14	24	13	2	1	·4999	558	·920
·090	1 909	322	46	17	30	16	2	1	·5557	536	·910
·100	0·992 231	352	040	021	037	020	003	001	± 0·6093	511	·900
·110	2 583	379	34	25	44	24	3	2	·6604	484	·890
·120	2 962	405	28	30	52	28	4	2	·7088	455	·880
·130	3 367	429	22	35	61	33	5	2	·7543	424	·870
·140	3 796	453	17	40	70	38	6	3	·7967	393	·860
·150	0·994 249	473	012	045	080	043	006	003	± 0·8360	358	·850
·160	4 722	492	08	51	090	48	07	4	·8718	324	·840
·170	5 214	509	05	57	100	53	08	4	·9042	287	·830
·180	5 723	524	02	63	111	59	09	5	·9329	250	·820
·190	6 247	537	01	69	122	65	10	5	·9579	211	·810
·200	0·996 784	547	000	076	133	071	011	005	± 0·9790	173	·800
·210	7 331	556	01	82	145	77	11	6	0·9963	133	·790
·220	7 887	561	02	89	157	84	12	6	1·0096	93	·780
·230	8 448	566	05	096	169	90	13	7	1·0189	53	·770
·240	9 014	568	09	103	181	097	14	7	1·0242	12	·760
·250	0·999 582	566	014	110	193	103	015	008	± 1·0254	28	·750
·260	1·000 148	564	19	116	205	110	16	08	1·0226	68	·740
·270	0 712	558	26	123	217	116	17	09	1·0158	108	·730
·280	1 270	551	34	130	229	123	18	09	1·0050	147	·720
·290	1 821	541	42	137	241	129	19	10	0·9903	186	·710
·300	1·002 362	529	051	143	253	135	020	010	± 0·9717	224	·700
·310	2 891	516	61	150	264	141	21	11	·0493	260	·690
·320	3 407	500	71	156	275	147	22	11	·9233	296	·680
·330	3 907	482	81	162	286	153	23	12	·8937	331	·670
·340	4 389	463	092	168	297	159	23	12	·8606	365	·660
·350	1·004 852	441	103	174	307	164	024	013	± 0·8241	396	·650
·360	5 293	418	113	179	316	169	25	13	·7845	427	·640
·370	5 711	394	124	185	325	174	26	13	·7418	455	·630
·380	6 105	368	134	190	334	178	27	14	·6963	482	·620
·390	6 473	340	144	194	342	183	27	14	·6481	507	·610
·400	1·006 813		153	198	349	187	028	014	± 0·5974		·600

Second Satellite.—Inequalities.

Arg.	Radius Vector. a_2		β_2	γ_2	δ_2	ϵ_2	κ_2	λ_2	Longitude. α_2		Arg.
·400	1·006 813		153	198	349	187	028	014	± 0·5974		·600
·410	7 124	311	161	202	356	190	28	15	·5444	530	·590
·420	7 406	282	169	206	362	194	29	15	·4893	551	·580
·430	7 658	252	177	209	368	197	29	15	·4324	569	·570
·440	7 877	219	183	212	373	199	29	15	·3737	587	·560
		187								600	
·450	1·008 064		189	214	377	201	030	015	± 0·3137		·550
·460	8 218	154	193	216	380	203	30	16	·2524	613	·540
·470	8 338	120	197	217	383	205	30	16	·1901	623	·530
·480	8 425	87	199	218	385	206	30	16	·1272	629	·520
·490	8 477	52	201	219	386	206	30	16	·0637	635	·510
		17								637	
·500	1·008494		202	219	386	206	030	016	± 0·0000		·500

Longitude (continued).

Arg.		β_2	γ_2	δ_2	ϵ_2	ζ_2	η_2	θ_2	ι_2	κ_2	λ_2	Arg.	
·00	·50	∓ ·0000	± ·0000	·0000	·0000	·0000	·0000	·0000	00	00	00	·50	·00
·01	·49	∓ 03	08	14	07	17	21	11	01	01	01	·51	·99
·02	·48	∓ 06	16	28	15	33	42	22	02	02	01	·52	·98
·03	·47	∓ 09	24	41	22	50	63	33	03	04	02	·53	·97
·04	·46	∓ 09	31	55	29	66	83	44	05	05	03	·54	·96
·05	·45	∓ ·0009	∓ ·0039	·0068	·0037	·0082	·0104	·0054	06	06	03	·55	·95
·06	·44	∓ 06	46	·0081	44	·0097	·0123	64	07	07	04	·56	·94
·07	·43	∓ 01	54	·0094	50	·0113	·0142	74	08	08	04	·57	·93
·08	·42	± 06	61	·0107	57	·0128	·0161	84	09	09	05	·58	·92
·09	·41	± 15	67	·0119	63	·0142	·0180	94	10	10	05	·59	·91
·10	·40	± ·0025	± ·0074	·0130	·0069	·0156	·0197	·0103	11	11	06	·60	·90
·11	·39	37	80	·0141	75	·0169	·0214	·0111	12	12	06	·61	·89
·12	·38	51	86	·0152	81	·0181	·0229	·0120	13	13	07	·62	·88
·13	·37	65	92	·0161	86	·0193	·0244	·0128	13	14	07	·63	·87
·14	·36	81	97	·0171	91	·0204	·0258	·0135	14	15	08	·64	·86
·15	·35	± ·0096	± ·0102	·0179	·0096	·0214	·0271	·0142	15	16	08	·65	·85
·16	·34	·0111	·0106	·0187	·0100	·0223	·0283	·0148	16	16	08	·66	·84
·17	·33	·0125	·0110	·0194	·0104	·0232	·0294	·0153	16	17	09	·67	·83
·18	·32	·0139	·0114	·0200	·0107	·0239	·0303	·0158	17	17	09	·68	·82
·19	·31	·0151	·0117	·0206	·0110	·0246	·0312	·0163	17	18	09	·69	·81
·20	·30	± ·0162	± ·0120	·0211	·0113	·0252	·0319	·0166	17	18	10	·70	·80
·21	·29	·0171	·0122	·0214	·0115	·0256	·0325	·0169	18	19	10	·71	·79
·22	·28	·0178	·0123	·0217	·0116	·0260	·0329	·0172	18	19	10	·72	·78
·23	·27	·0183	·0125	·0220	·0117	·0263	·0333	·0174	18	19	10	·73	·77
·24	·26	·0187	·0125	·0221	·0118	·0264	·0335	·0175	18	19	10	·74	·76
·25	·25	± ·0188	± ·0126	·0221	·0118	·0265	·0335	·0175	18	19	10	·75	·75

Third Satellite.—Inequalities.

Arg.	a_3		Radius Vector. β_3	γ_3	δ_3	e_3, t_3	Longitude. γ_3		δ_3	Arg.
·000	0·997 573	2	0000	0000	000	0	± ·0000	39	± °·0000	·000
·010	7 575	7	01	01	01	0	039	39	18	·990
·020	7 582	11	05	04	04	0	078	39	36	·980
·030	7 593	15	11	08	08	0	117	39	54	·970
·040	7 608	20	19	15	15	0	156	37	71	·960
·050	0·997 628	24	0029	0024	023	0	± ·0193	37	± ·0087	·950
·060	7 652	28	41	34	32	1	230	36	102	·940
·070	7 680	32	56	46	43	1	266	35	116	·930
·080	7 712	36	73	61	55	1	301	34	128	·920
·090	7 748	40	92	76	69	1	325	32	139	·910
·100	0·997 788	43	0113	0095	084	1	± ·0367	31	± ·0147	·900
·110	7 831	47	135	115	099	1	398	30	154	·890
·120	7 878	50	160	137	115	1	428	27	159	·880
·130	7 928	53	186	160	131	2	455	26	162	·870
·140	7 981	56	214	186	147	2	481	24	162	·860
·150	0·998 037	58	0243	0213	164	2	± ·0505	22	± ·0161	·850
·160	8 095	61	273	241	180	2	527	20	157	·840
·170	8 156	63	305	271	195	3	547	18	151	·830
·180	8 219	65	338	303	209	3	565	16	144	·820
·190	8 284	66	372	336	223	3	581	13	134	·810
·200	0·998 350	68	0407	0369	235	3	± ·0594	12	± ·0123	·800
·210	8 418	69	442	404	246	4	606	9	111	·790
·220	8 487	69	478	440	255	4	615	7	097	·780
·230	8 556	70	514	476	263	4	622	4	082	·770
·240	8 626	71	551	512	269	5	626	3	066	·760
·250	0·998 697	70	0588	0549	273	5	± ·0629	0	± ·0050	·750
·260	8 767	70	625	587	276	5	629	2	± 33	·740
·270	8 837	70	661	624	276	6	627	5	± 16	·730
·280	8 907	69	698	661	274	6	622	7	∓ 02	·720
·290	8 976	67	734	697	271	6	615	9	∓ 18	·710
·300	0·999 043	67	0769	0733	265	7	± ·0606	11	∓ ·0035	·700
·310	9 110	64	804	769	258	7	595	14	∓ 50	·690
·320	9 174	63	837	804	249	7	581	16	∓ 65	·680
·330	9 237	61	870	838	238	7	565	19	∓ 78	·670
·340	9 298	58	902	871	226	8	546	20	∓ 89	·660
·350	0·999 356	55	0932	0902	212	8	± ·0526	23	∓ ·0099	·650
·360	9 411	53	0961	0933	197	8	503	25	∓ 108	·640
·370	9 464	50	0989	0962	181	8	478	28	∓ 114	·630
·380	9 514	46	1015	0989	164	9	450	29	∓ 117	·620
·390	9 560	43	1039	1015	146	9	421	31	∓ 119	·610
·400	0·999 603		1061	1039	129	9	± ·0390		∓ ·0118	·600

Longitude and of Arguments.

		l_2-0	$\alpha_2\ \beta_2$	γ_2	$\delta_2 l$	ϵ_2	ι_2
h	m	°					
0	0	0·0	·0000	·0000	·000	·000	·000
	2	0·0699	02	02	0	0	0
	4	0·1398	04	04	0	0	0
	6	0·2097	06	06	0	1	1
	8	0·2795	08	08	0	1	1
0	10	0·3494	·0010	·0010	·001	·001	·001
	20	0·6989	19	20	1	2	2
	30	1·0483	29	30	2	3	3
	40	1·3977	39	39	2	4	4
	50	1·7471	49	49	3	5	5
1	0	2·0966	·0058	·0059	·003	·006	·006
	10	2·4460	·0068	·0069	4	7	7
	20	2·7954	·0078	·0079	4	8	8
	30	3·1449	·0087	·0089	5	9	9
	40	3·4943	·0097	·0098	6	·010	·010
	50	3·8437	·0107	·0108	6	·011	·011
2	0	4·1931	·0116	·0118	·007	·012	·012
	10	4·5426	·0126	·0128	7	·013	·013
	20	4·8920	·0136	·0138	8	·014	·014
	30	5·2414	·0146	·0147	8	·015	·015
	40	5·5908	·0155	·0157	9	·016	·016
	50	5·9403	·0165	·0167	9	·017	·016
3	0	6·2897	·0175	·0177	·010	·018	·017
	10	6·6391	·0184	·0187	·011	·019	·018
	20	6·9886	·0194	·0197	·011	·020	·019
	30	7·3380	·0204	·0207	·012	·021	·020
	40	7·6874	·0214	·0217	·012	·022	·021
	50	8·0368	·0223	·0227	·013	·023	·022
4	0	8·3863	·0233	·0236	·013	·024	·023
	10	8·7357	·0243	·0246	·014	·025	·024
	20	9·0851	·0252	·0256	·014	·026	·025
	30	9·4346	·0262	·0266	·015	·027	·026
	40	9·7840	·0272	·0276	·016	·028	·027
	50	10·1334	·0281	·0286	·016	·029	·028
5	0	10·4828	·0291	·0295	·017	·030	·029
	10	10·8323	·0301	·0305	·017	·031	·030
	20	11·1817	·0311	·0315	·018	·032	·031
	30	11·5311	·0320	·0325	·018	·033	·032
	40	11·8805	·0330	·0335	·019	·034	·033
	50	12·2300	·0340	·0345	·019	·035	·034
6	0	12·5794	·0349	·0355	·020	·036	·035

Third Satellite.—Inequalities.

Arg.	α_3		Radius Vector. β_3	γ_3	δ_3	ϵ_3, t_3	Longitude. γ_3		δ_3	Arg.
·000	0·997 573	2	0000	0000	000	0	± °0000	39	± °0000	·000
·010	7 575	7	01	01	01	0	039	39	18	·990
·020	7 582	11	05	04	04	0	078	39	36	·980
·030	7 593	15	11	08	08	0	117	39	54	·970
·040	7 608	20	19	15	15	0	156	37	71	·960
·050	0·997 628	24	0029	0024	023	0	± ·0193	37	± ·0087	·950
·060	7 652	28	41	34	32	1	230	36	102	·940
·070	7 680	32	56	46	43	1	266	35	116	·930
·080	7 712	36	73	61	55	1	301	34	128	·920
·090	7 748	40	92	76	69	1	325	32	139	·910
·100	0·997 788	43	0113	0095	084	1	± ·0367	31	± ·0147	·900
·110	7 831	47	135	115	099	1	398	30	154	·890
·120	7 878	50	160	137	115	1	428	27	159	·880
·130	7 928	53	186	160	131	2	455	26	162	·870
·140	7 981	56	214	186	147	2	481	24	162	·860
·150	0·998 037	58	0243	0213	164	2	± ·0505	22	± ·0161	·850
·160	8 095	61	273	241	180	2	527	20	157	·840
·170	8 156	63	305	271	195	3	547	18	151	·830
·180	8 219	65	338	303	209	3	565	16	144	·820
·190	8 284	66	372	336	223	3	581	13	134	·810
·200	0·998 350	68	0407	0369	235	3	± ·0594	12	± ·0123	·800
·210	8 418	69	442	404	246	4	606	9	111	·790
·220	8 487	69	478	440	255	4	615	7	097	·780
·230	8 556	70	514	476	263	4	622	4	082	·770
·240	8 626	71	551	512	269	5	626	3	066	·760
·250	0·998 697	70	0588	0549	273	5	± ·0629	0	± ·0050	·750
·260	8 767	70	625	587	276	5	629	2	± 33	·740
·270	8 837	70	661	624	276	6	627	5	± 16	·730
·280	8 907	69	698	661	274	6	622	7	∓ 02	·720
·290	8 976	67	734	697	271	6	615	9	∓ 18	·710
·300	0·999 043	67	0769	0733	265	7	± ·0606	11	∓ ·0035	·700
·310	9 110	64	804	769	258	7	595	14	∓ 50	·690
·320	9 174	63	837	804	249	7	581	16	∓ 65	·680
·330	9 237	61	870	838	238	7	565	19	∓ 78	·670
·340	9 298	58	902	871	226	8	546	20	∓ 89	·660
·350	0·999 356	55	0932	0902	212	8	± ·0526	23	∓ ·0099	·650
·360	9 411	53	0961	0933	197	8	503	25	∓ 108	·640
·370	9 464	50	0989	0962	181	8	478	28	∓ 114	·630
·380	9 514	46	1015	0989	164	9	450	29	∓ 117	·620
·390	9 560	43	1039	1015	146	9	421	31	∓ 119	·610
·400	0·999 603		1061	1039	129	9	± ·0390		∓ ·0118	·600

Third Satellite.—Inequalities.

	Radius Vector.					Longitude.			
Arg.	a_3		β_3	γ_3	δ_3	$\epsilon_3 \iota_3$	γ_3		δ_3	Arg.
·400	0·999 603	40	1061	1039	129	09	± ·0390	33	∓ ·0118	·600
·410	9 643	35	1082	1062	111	09	357	35	∓ 115	·590
·420	9 678	32	1101	1082	095	09	322	37	∓ 109	·580
·430	9 710	28	1117	1100	079	10	285	38	∓ 101	·570
·440	9 738	24	1132	1116	064	10	247	39	∓ 091	·560
·450	0·999 762	20	1144	1129	051	10	± ·0208	40	∓ ·0079	·550
·460	9 782	15	1154	1140	040	10	168	41	∓ 66	·540
·470	9 797	11	1162	1149	031	10	127	42	∓ 51	·530
·480	9 808	7	1168	1155	024	10	085	42	∓ 34	·520
·490	9 815	2	1172	1159	020	10	043	43	∓ 17	·510
·500	0·999 817		1173	1161	019	10	± ·0000		∓ ·0000	·500

Longitude (continued).

Arg.		α_3		β_3		ζ_3	η_3	θ_3	$\epsilon_3 \iota_3$	Arg.	
·000	·500	± ·0000	81	± ·0000	42	± ·0000	00	00	0	·500	·000
·010	·490	081	80	042	42	03	04	02	0	·510	·990
·020	·480	161	80	084	42	06	08	04	0	·520	·980
·030	·470	241	79	126	41	08	12	06	1	·530	·970
·040	·460	320	77	167	41	11	16	08	1	·540	·960
·050	·450	± ·0397	76	± ·0208	39	± ·0014	20	10	2	·550	·950
·060	·440	473	74	247	39	16	24	12	2	·560	·940
·070	·430	547	72	286	38	19	28	14	2	·570	·930
·080	·420	619	70	324	36	21	32	16	3	·580	·920
·090	·410	689	67	360	35	24	35	18	3	·590	·910
·100	·400	± ·0756	64	± ·0395	33	± ·0026	39	20	3	·600	·900
·110	·390	820	60	428	32	28	42	21	4	·610	·890
·120	·380	880	57	460	30	30	45	23	4	·620	·880
·130	·370	937	54	490	28	32	48	24	4	·630	·870
·140	·360	·0991	49	518	26	34	51	26	4	·640	·860
·150	·350	± ·1040	46	± ·0544	23	± ·0036	53	27	5	·650	·850
·160	·340	·1086	41	567	22	37	55	28	5	·660	·840
·170	·330	·1127	36	589	19	38	57	29	5	·670	·830
·180	·320	·1163	32	608	17	40	59	30	5	·680	·820
·190	·310	·1195	28	625	14	41	61	31	5	·690	·810
·200	·300	± ·1223	22	± ·0639	12	± ·0042	62	32	5	·700	·800
·210	·290	·1245	18	651	9	43	64	32	5	·710	·790
·220	·280	·1263	13	660	7	43	64	33	5	·720	·780
·230	·270	·1276	7	667	4	44	65	33	6	·730	·770
·240	·260	·1283	3	671		44	65	33	6	·740	·760
·250	·250	± ·1286		± ·0672		± ·0044	66	34	06	·750	·750

Fourth Satellite.—Inequalities.

Arg.	a_4		Radius Vector. β_4	γ_4	δ_4	ϵ_4	ζ_4	η_4	Longitude. α_4		β_4	Arg.
·000	0·992 420	15	000	000	000	0	0	17	±·0000	527	±00	·000
·010	2 435	43	0	0	0	0	0	17	·0527	525	01	·990
·020	2 478	72	1	1	0	0	0	17	·1052	521	01	·980
·030	2 550	101	1	2	1	0	0	17	·1573	515	02	·970
·040	2 651	129	2	4	2	0	0	17	·2088	506	02	·960
·050	0·992 780	157	003	007	003	1	0	16	±·2594	495	±02	·950
·060	2 937	184	5	10	4	1	0	16	·3089	483	03	·940
·070	3 121	209	7	14	5	1	0	16	·3572	469	04	·930
·080	3 330	235	09	18	7	2	1	16	·4041	452	04	·920
·090	3 565	260	011	22	9	2	1	15	·4493	434	05	·910
·100	0·993 825	283	013	027	011	3	1	15	±·4927	414	±05	·900
·110	4 108	304	16	33	13	3	1	15	·5341	393	06	·890
·120	9 412	326	19	39	15	4	1	15	·5734	370	07	·880
·130	4 738	346	22	45	17	5	1	14	·6104	345	08	·870
·140	5 084	363	25	52	20	5	2	14	·6449	319	08	·860
·150	0·995 447	380	028	059	023	6	2	13	±·6768	292	±09	·850
·160	5 827	396	32	66	25	7	2	13	·7060	264	10	·840
·170	6 223	409	36	74	28	8	2	12	·7324	235	11	·830
·180	6 632	421	40	82	31	9	2	12	·7559	204	13	·820
·190	7 053	431	44	90	35	9	3	11	·7763	173	14	·810
·200	0·997 484	440	048	099	038	10	3	11	±·7936	142	±15	·800
·210	7 924	446	53	107	41	11	3	10	·8078	110	17	·790
·220	8 370	452	58	116	44	12	3	10	·8188	77	18	·780
·230	8 822	454	63	125	48	13	4	9	·8265	45	20	·770
·240	9 276	456	69	134	51	14	4	9	·8310	11	23	·760
·250	0·999 732	456	075	143	055	15	4	8	±·8321	21	±23	·750
·260	1·000 188	453	081	152	58	16	5	8	·8300	54	24	·740
·270	0 641	450	088	161	62	17	5	7	·8246	86	26	·730
·280	1 091	444	095	170	65	18	5	7	·8160	118	27	·720
·290	1 535	436	102	179	68	18	5	6	·8042	150	29	·710
·300	1·001 971	427	109	187	072	19	6	6	±·7892	181	±30	·700
·310	2 398	416	117	196	75	20	6	5	·7711	211	31	·690
·320	2 814	404	125	204	78	21	6	5	·7500	240	32	·680
·330	3 218	389	133	212	81	22	6	4	·7260	268	33	·670
·340	3 607	374	141	220	84	23	7	4	·6992	296	33	·660
·350	1·003 981	358	149	227	087	24	7	3	±·6696	322	±34	·650
·360	4 339	339	158	234	90	24	7	3	·6374	346	33	·640
·370	4 678	319	166	241	92	25	7	3	·6028	369	33	·630
·380	4 997	298	174	247	95	26	7	2	·5659	392	32	·620
·390	5 295	276	182	253	97	26	8	2	·5267	412	31	·610
·400	1·005 571		189	259	099	27	8	2	±·4855		±30	·600

Longitude and of Arguments.

		$l_4 - 0$	α_4	β_4	$\gamma_\omega\ \delta_4$	ϵ_4	η_4
h	m	°					
0	0	0·0	·00000	·000	...	·000	·000
	2	0·0300	008	0	...	0	0
	4	0·0599	017	0	...	0	1
	6	0·0899	025	0	...	0	1
	8	0·1198	033	0	...	1	1
0	10	0·1498	·00042	·001	·000	·001	·002
	20	0·2996	083	1	1	2	3
	30	0·4494	125	2	1	2	5
	40	0·5992	166	2	2	3	6
	50	0·7490	208	3	2	4	8
1	0	0·8988	·00250	·003	·002	·005	·009
	10	1·0486	291	4	3	6	·011
	20	1·1984	333	4	3	7	·012
	30	1·3482	374	5	4	7	·014
	40	1·4980	416	6	4	8	·015
	50	1·6478	458	6	5	9	·017
2	0	1·7976	·00499	·007	·005	·010	·018
	10	1·9474	541	7	5	·011	·020
	20	2·0972	582	8	6	·012	·022
	30	2·2470	624		6	·012	·023
	40	2·3968	666	9	7	·013	·025
	50	2·5466	707	9	7	·014	·026
3	0	2·6964	·00749	·010	·007	·015	·028
	10	2·8462	791	·011	·008	·016	·029
	20	2·9960	832	·011	·008	·017	·031
	30	3·1458	874	·012	·009	·017	·032
	40	3·2956	915	·012	·009	·018	·034
	50	3·4454	957	·013	·010	·019	·035
4	0	3·5952	·00999	·013	·010	·020	·037
	10	3·7450	·01040	·014	·010	·021	·038
	20	3·8948	·01082	·014	·011	·022	·040
	30	4·0446	·01123	·015	·011	·022	·042
	40	4·1944	·01165	·016	·012	·023	·043
	50	4·3442	·01207	·016	·012	·024	·045
5	0	4·4940	·01248	·017	·012	·025	·046
	10	4·6438	·01290	·017	·013	·026	·048
	20	4·7936	·01331	·018	·013	·027	·049
	30	4·9434	·01373	·018	·014	·027	·051
	40	5·0932	·01415	·019	·014	·028	·052
	50	5·2430	·01456	·019	·015	·029	·054
6	0	5·3928	·01498	·020	·015	·030	·055

Fourth Satellite.—Inequalities.

Arg.	α_4		Radius Vector. β_4	γ_4	δ_4	ϵ_4	ζ_4	η_4	Longitude. α_4		β_4	Arg.
·000	0·992 420	15	000	000	000	0	0	17	± ·0000	527	± 00	·000
·010	2 435	43	0	0	0	0	0	17	·0527	525	01	·990
·020	2 478	72	1	1	0	0	0	17	·1052	521	01	·980
·030	2 550	101	1	2	1	0	0	17	·1573	515	02	·970
·040	2 651	129	2	4	2	0	0	17	·2088	506	02	·960
·050	0·992 780	157	003	007	003	1	0	16	± ·2594	495	± 02	·950
·060	2 937	184	5	10	4	1	0	16	·3089	483	03	·940
·070	3 121	209	7	14	5	1	0	16	·3572	469	04	·930
·080	3 330	235	09	18	7	2	1	16	·4041	452	04	·920
·090	3 565	260	011	22	9	2	1	15	·4493	434	05	·910
·100	0·993 825	283	013	027	011	3	1	15	± ·4927	414	± 05	·900
·110	4 108	304	16	33	13	3	1	15	·5341	393	06	·890
·120	9 412	326	19	39	15	4	1	15	·5734	370	07	·880
·130	4 738	346	22	45	17	5	1	14	·6104	345	08	·870
·140	5 084	363	25	52	20	5	2	14	·6449	319	08	·860
·150	0·995 447	380	028	059	023	6	2	13	± ·6768	292	± 09	·850
·160	5 827	396	32	66	25	7	2	13	·7060	264	10	·840
·170	6 223	409	36	74	28	8	2	12	·7324	235	11	·830
·180	6 632	421	40	82	31	9	2	12	·7559	204	13	·820
·190	7 053	431	44	90	35	9	3	11	·7763	173	14	·810
·200	0·997 484	440	048	099	038	10	3	11	± ·7936	142	± 15	·800
·210	7 924	446	53	107	41	11	3	10	·8078	110	17	·790
·220	8 370	452	58	116	44	12	3	10	·8188	77	18	·780
·230	8 822	454	63	125	48	13	4	9	·8265	45	20	·770
·240	9 276	456	69	134	51	14	4	9	·8310	11	23	·760
·250	0·999 732	456	075	143	055	15	4	8	± ·8321	21	± 23	·750
·260	1·000 188	453	081	152	58	16	5	8	·8300	54	24	·740
·270	0 641	450	088	161	62	17	5	7	·8246	86	26	·730
·280	1 091	444	095	170	65	18	5	7	·8160	118	27	·720
·290	1 535	436	102	179	68	18	5	6	·8042	150	29	·710
·300	1·001 971	427	109	187	072	19	6	6	± ·7892	181	± 30	·700
·310	2 398	416	117	196	75	20	6	5	·7711	211	31	·690
·320	2 814	404	125	204	78	21	6	5	·7500	240	32	·680
·330	3 218	389	133	212	81	22	6	4	·7260	268	33	·670
·340	3 607	374	141	220	84	23	7	4	·6992	296	33	·660
·350	1·003 981	358	149	227	087	24	7	3	± ·6696	322	± 34	·650
·360	4 339	339	158	234	90	24	7	3	·6374	346	33	·640
·370	4 678	319	166	241	92	25	7	3	·6028	369	33	·630
·380	4 997	298	174	247	95	26	7	2	·5659	392	32	·620
·390	5 295	276	182	253	97	26	8	2	·5267	412	31	·610
·400	1·005 571		189	259	099	27	8	2	± ·4855		± 30	·600

Fourth Satellite—Inequalities.

Arg.	Radius Vector. α_4		β_4	γ_4	δ_4	ϵ_4	ζ_4	η_4	Longitude. α_4		β_4	Arg.
·400	1·005 571	253	189	259	099	27	8	2	± ·4855	430	± 30	·600
·410	5 824	230	196	264	101	27	8	1	·4425	448	28	·590
·420	6 054	204	203	269	103	28	8	1	·3977	463	26	·580
·430	6 258	179	209	273	104	28	8	1	·3514	477	23	·570
·440	6 437	152	214	276	106	29	8	1	·3037	488	20	·560
·450	1·006 589	126	219	279	107	29	8	0	± ·2549	498	± 17	·550
·460	6 715	98	223	282	108	29	9	0	·2051	506	14	·540
·470	6 813	70	226	284	108	29	9	0	·1545	511	11	·530
·480	6 883	42	229	285	109	29	9	0	·1034	516	07	·520
·490	6 925	14	230	286	109	30	9	0	·0518	518	04	·510
·500	1·006 939		230	286	109	30	9	0	± ·0000		± 00	·500

Longitude (continued).

Arg.		γ_4	δ_4	ϵ_4	ζ_4	η_4, β_4	Arg.	
·000	·500	± ·0000	± ·0000	± 00	± 0	± 0	·500	·000
·010	·490	10	04	01	0	0	·510	·990
·020	·480	21	08	01	1	1	·520	·980
·030	·470	31	12	02	1	1	·530	·970
·040	·460	41	16	03	2	1	·540	·960
·050	·450	± ·0051	± ·0019	± 04	± 2	± 1	·550	·950
·060	·440	61	23	04	3	2	·560	·940
·070	·430	70	27	05	3	2	·570	·930
·080	·420	79	30	06	3	2	·580	·920
·090	·410	88	34	06	4	3	·590	·910
·100	·400	± ·0097	± ·0037	± 07	± 4	± 3	·600	·900
·110	·390	105	40	07	4	3	·610	·890
·120	·380	112	43	08	5	3	·620	·880
·130	·370	119	46	09	5	3	·630	·870
·140	·360	126	48	09	5	4	·640	·860
·150	·350	± ·0133	± ·0051	± 09	± 6	± 4	·650	·850
·160	·340	139	53	10	6	4	·660	·840
·170	·330	144	55	10	6	4	·670	·830
·180	·320	149	57	11	6	4	·680	·820
·190	·310	153	58	11	7	4	·690	·810
·200	·300	± ·0156	± ·0060	± 11	± 7	± 4	·700	·800
·210	·290	159	61	11	7	5	·710	·790
·220	·280	161	61	11	7	5	·720	·780
·230	·270	163	62	12	7	5	·730	·770
·240	·260	164	62	12	7	5	·740	·760
·250	·250	± ·0164	± ·0063	± 12	± 7	± 5	·750	·750

Ephemeris for Physical Observations of the Moon. By A. Marth.

1891, September 10 to October 28.

Greenwich Noon.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration. Sel. Long. of the Earth.	Geocentric Libration. Lat. of the Earth.	Geocentric Libration. Combined Amount.	Direction.
1891.	°	°	°	°	°	°
Sept. 10	355·93	+1·47	−7·06	+0·81	7·11	83·4
11	8·13	1·46	7·60	2·23	7·92	73·6
12	20·33	1·45	7·74	3·58	8·53	65·1
13	32·52	1·45	7·41	4·78	8·81	57·0
14	44·70	1·44	6·57	5·74	8·71	48·7
15	56·88	1·43	5·22	6·37	8·23	39·2
16	69·05	1·42	3·44	6·59	7·43	27·5
17	81·22	1·41	−1·36	6·35	6·50	12·1
18	93·38	1·39	+0·82	5·66	5·72	351·8
19	105·55	1·38	2·92	4·57	5·42	327·5
20	117·72	1·36	4·75	3·17	5·71	303·8
21	129·89	1·35	6·19	+1·60	6·39	284·5
22	142·06	1·33	7·18	−0·03	7·18	269·7
23	154·24	1·31	7·70	1·61	7·86	258·1
24	166·43	1·29	7·78	3·05	8·36	248·5
25	178·63	1·28	7·49	4·30	8·63	240·0
26	190·83	1·26	6·90	5·30	8·69	232·3
27	203·03	1·24	6·06	6·03	8·54	225·0
28	215·24	1·23	5·04	6·48	8·20	217·7
29	227·46	1·21	3·90	6·63	7.69	210·3
30	239·67	+1·19	+2·67	−6·50	7·02	202·2
Oct. 10	1·79	+1·03	−7·34	+4·68	8·70	57·3
11	13·97	1·01	7·10	5·67	9·08	51·2
12	26·15	0·99	6·41	6·37	9·03	45·0
13	38·32	0·97	5·28	6·70	8·53	38·1
14	50·48	0·94	3·75	6·61	7·60	29·4
15	62·64	0·91	−1·91	6·07	6·36	17·4
16	74·79	0·89	+0·10	5·10	5·10	359·9
17	86·94	0·87	2·10	3·77	4·34	330·9
18	99·09	0·84	3·93	2·19	4·50	299·2
19	111·24	0·81	5·46	+0·49	5·48	275·2
20	123·39	0·78	6·58	−1·20	6·68	259·7
21	135·55	0·76	7·26	2·76	7·76	249·1
22	147·71	0·73	7·49	4·13	8·55	241·1

Greenwich Noon.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration. Sel. Long. of the Earth.	Geocentric Libration. Lat. of the Earth.	Geocentric Libration. Combined Amount.	Direction.
1891.	°	°	°	°	°	°
Oct. 23	159·88	0·70	7·32	5·23	8·99	234·3
24	172·06	0·67	6·80	6·04	9·09	228·2
25	184·24	0·65	5·98	6·56	8·87	222·0
26	196·42	0·62	4·95	6·77	8·38	216·0
27	208·61	0·60	3·76	6·68	7·66	209·2
28	220·81	+0·57	+2·48	−6·30	6·77	201·4

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Observations of the Planet Jupiter and his Satellites during 1890 *with the* 12*-inch Equatoreal of the Lick Observatory.* By E. E. Barnard, M.A.

During 1890 I paid considerable attention to observations of *Jupiter*. The planet was observed on forty-nine nights with the 12-inch equatoreal.

Careful observations of transits of the principal markings were obtained and a number of filar micrometer measures of the different spots were made.

Special attention was given to a number of small black spots which were distributed around the planet in north latitude about 13°, and which were placed on the northern edge of the great equatorial belt. In all there were six of these singular objects. At the end of August these had about the following longitudes (referred to Marth's System II.): 41°—104°—213° —258°—327°—352°. They were essentially all on the same parallel of latitude, as shown by the measures of their positions on the disc.

I first saw these spots when observing *Jupiter* on April 26, 1890. They were then quite black and round and about 1″ in diameter, and very much resembled shadows of the satellites. Later, however, they were of a dark reddish colour when best seen. They finally became slightly elongated in the direction of rotation—about 1 : 2. Some of them were intimately associated with a number of very singular reddish spurs or "horse-tails,"

which jutted out from the northern edge of the equatorial belt and streamed following for some 30°. The black spots were on these horse-tails, and seemed to retain their first positions on them with remarkable constancy—the spot and horse-tail having apparently the same rotation period—which was some ten seconds more rapid than that of the Red Spot. A number of measures were made of the distance between one of these spots and the root of one of the horse-tails, but from observations extending over more than a month no trustworthy change was observed. The matter inside the equatorial belt, however, has a very rapid relative motion.

When first seen two of these small spots were directly north of the Red Spot, and separated from each other by about 8″ or 10″. I have numbered this system of spots 1, 2 . . . 6, beginning with the first of the two directly north of the Red Spot.

The spots in the order of my numbering would roughly have the following longitudes on September 1, 1890:

(1) $\lambda = 327°$. (2) $\lambda = 352°$. (3) $\lambda = 41°$.
(4) $\lambda = 104°$. (5) $\lambda = 213°$. (6) $\lambda = 258°$.

I was curious to know if these objects had any relative motion among themselves, and also to see if there was any change of latitude. Spots 1 and 2 offered a fine opportunity to test these points. I therefore selected them for a series of micrometer measures.

The distance between the two was repeatedly measured throughout the opposition of the planet, and their distances from the south and north limbs of *Jupiter* were also determined. These measures were always made when one or the other of the spots was in transit. I do not think that any actual change of latitude, nor any change in the distance between these spots, is shown. There is, perhaps, a very slight and irregular change in the distance, but probably no more than may be accounted for in the measures themselves. In the latitudes a difference of 1° only represents a discrepancy of 0″·3. An equatorial diameter of 38″·7 was used in deducing the latitudes.

These black spots were nearly all of the same size and appearance. Spot 1 was slightly larger than 2, and 5 was the smallest of all.

There were a number of white spots in the southern hemisphere, principally on a parallel just south of the Red Spot. These were small and round, about 1″ to 2″ in diameter, and very much resembled satellites in transit.

I singled out one of these which was south following the Red Spot, and secured some transits of it. This spot was conspicuous and larger than the average, and had a rather rapid motion with reference to the Red Spot. It and another, some 20° or 30° preceding it, were at the ends of the long dark streak or spot

which is shown in Mr. Keeler's drawing in *Monthly Notices*, vol. li. No. 1, close south of the Red Spot. This white spot, at first sharply defined and round, gradually dissipated and became diffused and hazy, and was finally lost through extreme dilution, though it was followed until it had completely passed the Red Spot.

My observations of this and of several other white spots in the southern hemisphere lead me to believe that they make their appearance as bright and clearly-defined spots, and that after an ephemeral existence they finally fade and die out like a melting cloud, to which they are probably analogous.

In reference to the long dark spot south of the Red Spot in Mr. Keeler's drawing, it seemed to undergo a transformation in passing the Red Spot. At first it was merely a portion of the dusky region on which the white spots were located, and was hemmed in between the two bright spots just mentioned. It quite rapidly darkened as it approached the Red Spot, and assumed a definite form—that of a short dark streak, tolerably well defined. I am rather inclined to think that this was not the dark spot to which Mr. Williams called attention (*Monthly Notices*, June 1890), for its appearance near the Red Spot was rather sudden, due to the rapid darkening already mentioned. About the time Mr. Williams speaks of seeing his spot I saw a diffused dusky object following the Red Spot, and bridging the bright space just south of the equatorial belt. This must of necessity have passed over or beneath the Red Spot through its motion; when nearing the great spot, however, it rather rapidly diffused, and finally disappeared. It would be interesting if Mr. Williams could settle this point, since the oblong spot still exists, and retains the same latitude it had when passing the Red Spot, though it is now several hours ahead of the latter object. I have given a few observations of transits of this object in Table III. column 11.

In reference to the Great Red Spot, after passing through several years of extreme faintness, it is again assuming the characteristic appearance of the first few years of its existence. During 1890 it had recovered much of its former distinctness, and at the few observations of this year (1891) it is still more distinct. During 1890 the preceding end was always more difficult to observe than the following end, which was better defined. A light cloud seemed to rest over the middle of the Spot.

Following are some measures of the length and position of the Great Spot:—

1890.			
July 30	Distance of centre	from	south limb = 14″·5 = 11″·2 at Δ = 5·20
Oct. 27	,,	,,	south limb = 11·7 = 10·9 at Δ = 5·20
Oct. 27	,,	,,	north limb = 25·3 = 23·5 at Δ = 5·20

Observations at or close to the time of transit of spot:—

Sept. 14*	Length of Red Spot	12″·1 = 10″·0	at Δ = 5·20
Oct. 27†	„	„ 11·4 = 10·6	at Δ = 5·20

In reference to the discussion that has arisen over the statement that the dark belt south of the Red Spot had overlapped the south part of the Red Spot, I would say that my observations are entirely in accord with Mr. Keeler's beautiful and accurate drawing of *Jupiter* in *Monthly Notices*, vol. li. No. 1.‡

At no time during my observations has any marking on the planet ever overlapped any portion of the Great Spot. In *Publications of the Astronomical Society of the Pacific*, No. 5, p. 91, I have called special attention to this apparent isolation of the Red Spot. It has throughout shown a repulsive force towards the other markings on the planet. At an observation on April 26, 1890, however, the diffused belt south seemed in contact with the south edge of the Red Spot. This perhaps with a small instrument might appear as an overlapping.

Several interesting black transits of the satellites III. and IV. were observed.

1890, August 13. The fourth satellite transited as a black spot, remarkable for its intense blackness. For a full account of this see *Pub. A. S. P.*, No. 10. With first-class seeing and the highest powers the satellite was perfectly round and black.

1890, Sept. 2. The third satellite transited as a black spot. See *Pub. A. S. P.*, No. 11, for a description of this transit.

1890, Sept. 9. The third satellite transited as a black spot. Following are a few notes on this transit.

III. is nearing first contact at transit. It is whiter than any portion of *Jupiter*. Contacts at entrance observed.

Mt. Hamilton M.T. $7^h\ 24^m$ on the disc. Still whiter than any portion of the planet.

$7^h\ 34^m$. Pale now but still distinctly seen.

$7^h\ 37^m$. Just perceptible as a v.v. pale spot.

$7^h\ 41^m$. V.v. faint. There is a *small* dusky speck close following.

$7^h\ 44^m$. It is small and dark.

$7^h\ 49^m$. It is quite dark and very small.

$7^h\ 56^m$. The satellite is black. It is a little smaller than either of the two black spots (1 and 2).

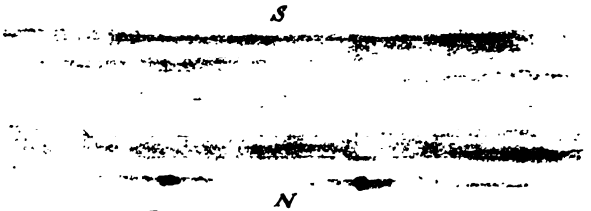
$9^h\ 34^m$. It is still very dark, but it has not been as black as was IV. at the transit of Aug. 13. It is larger and blacker than either of the small spots.

1891, Nov. 27. When three-quarters across the disc the third

* Measured at $7^h\ 17^m$. † Measured at transit of *p* end.

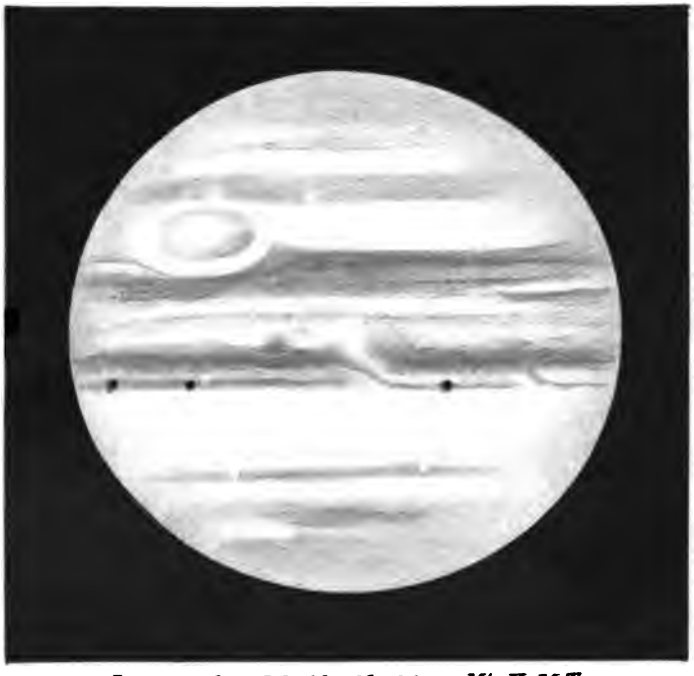
‡ Mr. Keeler's drawings should receive the very highest weight, as he has a real artistic ability such as very few observers possess.

FIG. 2.



Equatorial Belt, Horse tails, and Black Spots. 1890, July 30.

FIG 1.

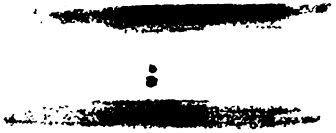


Jupiter, 1890, July 30, 10h. 20m., Mt. H. M. T.

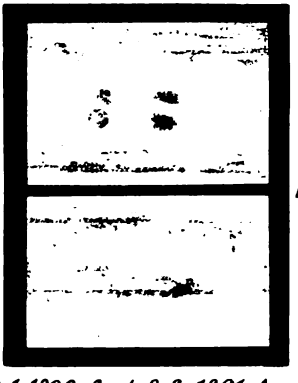
FIG. 3

Satellite IV at egress. 1890 Aug. 13.

FIG. 4.



Double Transit of Sat. 1 1890 Sept. 8.



Sat. 1, 1890 Sept. 8 & 1891 Aug.

E.E. Barnard, del.

satellite was very dark. Later, when off the disc, it appeared less than the other satellites.

I send a series of sketches of the appearances of Satellite IV. when emerging from transit 1890, Aug. 13 (Plate 14, fig. 3).

On this occasion as the satellite emerged it seemed to leave behind it a small dark spot which apparently remained stationary and diminished in size, as the satellite receded, until it became lost through exceeding smallness.

In connection with the black transits of III. and IV. I have often seen I. transiting as a dark or dusky spot. On Sept. 8, 1890, with the 12-inch this satellite presented a remarkable aspect while in dark transit. I noticed that it appeared elongated in a direction nearly perpendicular to the belts of *Jupiter*.

With high powers (500 and 700) and perfect definition the satellite appeared distinctly double, the components clearly separated. At my request Mr. Burnham kindly examined the satellite with me, and we both distinctly saw the phenomenon of apparent duplicity (see *Ast. Nach.* 2995). In reference to the *appearance* of the satellite—whatever may be the explanation—Mr. Burnham has no hesitation in stating that it was as distinctly double as any double star that he has seen. The distance between the centres of the two images was about 1″, and the position angle at transit 173°±. The south component was very slightly the smaller (Plate 14, fig. 4). It was not possible to follow the satellite closely, because of interruption by a number of visitors, and the great telescope was not available for observing the phenomenon.

I have offered two explanations of this phenomenon (*A.N.* 2995).

1st. That the satellite had a white belt on it parallel to those of *Jupiter*, or

2nd. That the satellite is actually double. I do not now think that the first of these theories is satisfactory, as it would require a far whiter belt than we have reason to believe will exist on the satellite, reasoning from our knowledge of the phenomena of *Jupiter* itself. I am strongly inclined to favour the theory of actual duplicity.

It may be asked, If the satellite is double why has it not so been seen when projected on the sky, if the distance is as much as one second? In the case of two stars this distance would be very easy with any considerable telescope. We must remember, however, that in the case of a double satellite we should have two sensible discs, which would perhaps never be well enough defined to show a maximum separation of only one second, while the greater part of the time the distance would be much less than this. If, however, the satellite were projected on a background brighter than itself it would appear reduced to its minimum size, so that if duplicity existed the chances for detecting it would be far more favourable. To better illustrate my meaning: Mercury is a very brilliant object to the naked eye about the

times of its greatest elongation. Yet when this planet crosses the Sun it is shorn of its light and cannot be seen with the unaided eye, though it is then a fifth nearer to us. On this same principle if the satellite consists of two moons the largeness of their ill-defined discs would make them appear as one in a telescope. Transferred, however, to a bright surface, the confusing light is got rid of and the size of the object is reduced to a minimum, and if double then will be the most favourable time to detect it.

If this satellite is really double, the components at the time of my observation were probably at their greatest elongation. If so this would indicate a distance from centre to centre of some 2,000 miles. The individual components would be about 1,000 miles in diameter, and their orbits nearly perpendicular to that of *Jupiter*, with a period of revolution of a few hours.

I trust that this satellite at its transits this year will receive the closest attention with powerful telescopes. It should be examined with the highest powers, and the direction of elongation, if any, carefully noted. If double, I have not much hope of the components ever being seen when projected on the sky.

In reference to the abnormal or black transits of the third and fourth satellites, from an experience of many years in actually observing the phenomenon I should feel much hesitation in endorsing the theory that they are due alone to contrast. I have seen these satellites cross the same regions of *Jupiter's* disc in bright transit and again like drops of ink. Assuming the albedo of the satellite to be approximately constant, that of *Jupiter* would need to vary so vastly that it must rank as a variable star.

In speaking upon this matter Mr. John Tebbutt, in *Pub. A. S. P.*, makes a statement that is certainly not upheld by observation. He says, "Further, a dark phase does not take place when the satellite crosses the polar regions of the planet." In *Pub. A. S. P.*, No. 5, pp. 108, 109, I have given a series of observations of the phenomena of *Jupiter* and his satellites, made with a 5-inch refractor at Nashville, Tenn., from which I quote—

"1880, December 30, $8^h\ 30^m$. Satellite III. seen in a high south latitude as a small black spot; continued visible as a black spot until near p. limb, and only lost its blackness at $9^h\ 4^m$."

"1886, May 8, $9^h\ 20^m$. Satellite IV. near north pole; very black."

Perhaps there would be no trouble in finding other instances where the satellites have been seen black in the polar regions.

I have never been able, in twelve years' time, to witness the phenomenon of a satellite shining through the limb of *Jupiter*—*i.e.* visible through the planet after the satellite had disappeared behind it in occultation. I have carefully watched a number of occultations with this subject specially in view, but, though the seeing on many of these occasions was perfect, no trace of any

of the satellites could ever be seen after the last contact at occultation. I have, therefore, come to the conclusion that this phenomenon, which has been reported by several observers, is exceedingly rare, or it is wholly beyond the reach of a first-class 5- or 12-inch telescope.

In the drawing of *Jupiter* for July 30, 1890 (Plate 14, fig. 1), I have given a careful delineation of the principal markings. Under favourable circumstances there is always such a vast amount of fine detail shown on the planet with the 12-inch that an accurate representation of it all is quite hopeless. On this drawing are shown three of the small black spots, Nos. 1, 2, and 3. Later in the same night I have given a more detailed drawing (Plate 14, fig. 2) of the equatorial belt and its appendages—the "horse-tails." This also shows spots 3 and 4, and their relation to the "horse-tails."

In the following tables are the observations and measures. They need but very slight explanation.

In Table I. Δ S.P. and Δ N.P. are the apparent distances of the satellites from the south and north limbs of *Jupiter*. "Time for Δ" in the last column gives the time of the measures of the satellites' position.

In Table II. Obs. Δ (I.–II.) is the value by direct measurement of the distance between spots 1 and 2; while 5·20 Δ (I.–II.) is the same quantity reduced to distance 5·20; so also for the quantities Δ N.P. and Δ S.P., which are the values for the distances from the north and south limbs. $\alpha\beta$ are the Jovicentric latitudes as derived from the measures, and which have been corrected for the elevation of the earth above *Jupiter's* equator by the aid of Mr. Marth's invaluable ephemeris. In the ninth column is given the number of the observed spot.

In Table III. P, M, F are the preceding end, middle, and following end of the Red Spot. Column 11 contains the observation of the oblong dusky spot shown close south of Red Spot in Mr. Keeler's drawing. The white spot in column 12 was at the following end of the dusky spot just mentioned. The measurements of the positions of the small black spots were derived from two to three settings of the wires. Although they were usually very conspicuous, it was found that they were quite ill-defined and rather difficult when the wires were placed over them.

Observations of the Satellites.

Mount Hamilton Mean Time.

Table I.

Date. 1890.	Satellite.	First Cont. h m s	Bisection. h m s	Last Cont. h m s	Mid. Tran. h m	Δ S.P. "	Δ N.P. "	Time for Δ. h m
April 26	III. Tr. Egr.	16 3 27	16 6 7	16 8 56				
July 8	I. Tr. Egr.	11 10 4	11 12 1	11 13 9				
30	I. Oc. Imm.	11 22 39	11 24 59	11 26 0				
Aug. 13	IV. Sh. Ing.	10 57 8	10 59 3	11 3 32				
13	IV. Tr. Egr.	...	12 4 30	...	9 42·2	28·4	18·2	10 21
22	III. Oc. Imm.	...	10 45 8	10 48 43				
28	II. Oc. Imm.	9 35 28	9 37 12	9 38 36				
31	I. Oc. Imm.	7 6 39	7 17 54					
Sept. 1	I. Sh. Tr. Egr.	7 25 15	7 26 37	7 28 47				
2	III. Sh. Ing.	...	7 7 9	7 11 7				
2	III. Tr. Egr.	7 18 15	7 21 5	7 25 55	...	26·0	19·7	6 52
8	I. Tr.	...	...	...	7 24·7	21·9	22·8	7 33
9	III. Tr. Ing.	7 17 20	7 19 59	7 22 24	9 1·9	25·2	19·4	8 18
Oct. 27	IV. Oct. Imm.	7 15 4	7 18 49	7 21 48				
Nov. 20	III. Sh. Imm.	...	6 52 5	...				
1891. July 4	I. Tr. Egr.	...	13 26 56	...				

July 8.—The times a little uncertain. Aug. 13.—Black transit of IV. Sept. 2.—Black transit of III.
Sept. 8.—I. apparently double. Sept. 9—Black transit of III.

Micrometer Measures of the Small Dark Spots.

TABLE II.

	Obs. Δ(I.–II.)	5·20 Δ(I.–II.)	Obs. ΔS.P.	5·20 ΔS.P.	Obs. ΔN.P.	5·20 ΔN.P.	χ_{β}.	Spot.
1890.	"	"	"	"	"	"	°	
July 30	...	...	29·6	23·2	17·2	13·5	+13·7	I 2
Aug. 1	...	...	29·6	23·2	17·2	13·5	+13·7	I·2
	10·4	8·2	...	...	...	...	...	I·2
11	10·3	8·1	29·2	22·9	16·7	13·1	+13·9	6
13	...	...	28 4	22·4	18·2	14·3	+11·3	I·2
18	9·9	7·8	28·3	22·4	19·0	15·1	+10·3	I·2
25	10·5	8·4	29 6	23·7	17·4	13·9	+13·5	I·2
26	...	...	28·6	22·9	17·5	14·0	+12·5	3
28	9·6	7·7	...	...	...	...	...	I·2
Sept. 5	...	...	29·2	23·8	18·2	14·8	+12·6	4
14	8·2	6·9	...	...	...	...	...	I·2
21	8·6	7·4	27·6	23·7	16·9	14 5	+12·9	I·2
Oct. 12	7·5	6·9	25·3	23·1	15 5	14·1	+12·6	I·2
20	7·4	6·9	24·2	22·5	15·5	14·5	+11·3	I·2
26	...	...	24·1	22·9	14·2	13·5	+13·2	5
27	7·6	7·3	24·2	23·2	14·1	13·5	+13·8	I·2
Nov. 20	7·8	8·0	24·0	24·5	12·9	13·2	+14·6	I·2
1891.								
May 14	8·0	8·2	21·5	22·1	14·2	14·6	+12·2	I·2
July 4	7·4	6·4	25·6	22·1	15·9	13·7	+13·9	I·2

The above measures were made at the time of the objects' central transit.

Mount Hamilton Mean Time of Observed Transits of Spots.

TABLE III.

	Red Spot.			Small Black Spots.						Oblong Spot.	White Spot.
	P	M	F	1	2	3	4	5	6		
1890.	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
April 26	15 49·3	16 0·7	16 23·2	15 53·2							
July 8	...	11 16·3	11 38·3	...	11 20·3						
13	...	...	...	...	...	11 55·5					
14	...	...	...	...	...	...	12 30·4				
15	...	12 9·5	12 29·5	...	12 13·0	13 37·3					
30	...	9 22·9	9 48 8	...	9 35·8	10 48·6	...	...	...	...	10 11·2
Aug. 1	10 36·6	11 1·0	11 23·4	10 17·6	11 3·0	...	...	...	...	...	11 47·9
2	...	...	...	...	...	9 42·9					
6	...	...	...	...	...	11 30·6	...	...	...	...	10 59·2
8	...	...	...	11 3·8							
11	...	...	...	8 32·4	...	...	...	...	...	...	9 58·0
13	...	11 ·5	...	...	11 1·0						
17	...	...	...	...	...	...	...	...	1 29·0		
18	9 37·9	10 2·4	10 25·3	...	10 0·9	...	...	...	...	...	10 32·3
21	...	...	...	...	...	8 43·2					
25	...	10 40·5	...	9 58·0	10 39·5						
26	...	...	...	...	...	7 52·1	9 37				

	Red Spot.			Small Black Spots.						Oblong Spot.	White Spot.
	P	M	F	1	2	3	4	5	6		
1890.	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
Aug. 28	7 52·0	8 10·4	...	...	8 8·9						
Sept. 1	...	...	...	...	...	...	7 35·3				
2	...	7 26·3	...	...	7 18·0						
5	...	...	...	...	...	...	7 39·7				
9	...	8 6·7	...	7 19·9							
11	...	...	...	...	...	10 57	...	7 6·5			
14	6 55·5	±7 17·4	7 42·3	...	7 5·5						
21	...	8 10·1	8 35·0	7 17·2	7 51·1						
Oct. 12	...	...	...	...	10 5·3	...	...	...	...	...	10 5·
20	...	7 8·6	...	...	6 45·2						
26	...	...	...	...	...	...	7 54·6				
27	7 33·8	7 56·6	...	6 50·9	7 33·8						
28	...	...	...	...	...	...	6 16·0				
29	...	...	...	8 31·0	...	...	6 47·0	...	..	6 53·4	
Nov. 20	...	...	...	6 41·3							
1891.											
June 5	...	16 27·3									
July 4	...	...	...	12 33							

Longitudes of Spots, Referred to Marth's System II.

TABLE IV.

Date. 1890.	Red Spot. P	M	F	Small Black Spots. 1	2	3	4	5		Oblong Spot.	White Spot.
	°	°	°	°	°	°	°	°	°	•	°
April 26	346·0	352·9	6·5	348·4							
July 8	...	355·5	8·8	...	257·9						
13	...	...	...	...	...	51·2					
14	...	...	...	...	...	...	...	222·9			
15	...	360·5	12·6	...	364·7	53·6					
30	...	355·9	11·5	...	363·7	47·7	...	...	...	...	25·1
Aug. 1	341·3	356·0	9·5	329·8	357·2	...	...	...	...	...	24·2
2	...	...	...	...	...	...	...	...	260·9		
6	...	...	...	...	...	45·8	...	...	...	...	26·9
8	...	...	...	330·5							
11	...	...	...	330·0	...	.·.	...	...	...	...	21·7
13	...	361·5	...	...	360·6						
17	...	...	..	...	...	...	...	...	359·1		
18	342·2	357·0	10·7	...	356·1	...	...	...	...	...	15·0
21	...	...	...	...	...	40·0					
25	...	352·3	...	326·7	351·7						
26	...	...	...	...	...	40·8	104·2				
28	341·5	352·6	...	...	351·6						

Date.	Red Spot. P	Red Spot. M	Red Spot. F	Small Black Spots. 1	2	3	4			Oblong Spot.	White Spot.
1890.	°	°	°	°	°	°	°	°	°	°	°
Sept. 1	...	...	...	...	...	...	...	218·7			
2	...	357·4	...	...	352·4						
5	...	...	...	...	...	...	96·3				
9	...	353·9	...	325·6							
11	...	...	...	...	...	37·3	...	...	258·0		
14	342·0	355·2	10·3	...	348·0						
21	...	358·8	13·7	326·8	347·4						
Oct. 12	...	356·5	...	...	342·2	...	...	...	...	...	342·2
20	...	356·5	...	...	342·3						
26	...	...	...	...	...	...	...	205·0			
27	342·4	356·2	...	316·5	342·4						
28	...	...	...	...	...	...	85·4				
29	...	...	...	317·4	...	...	...	...	354·4	258·3	
Nov. 20	...	...	...	314·5							
23	...	357·8									
1891.											
June 5	...	3·1									
July 4	...	...	...	260·1							

Oct. 12. Perhaps the white spot observed is not the one previously noted. The transit refers to a white spot on the parallel of the one observed before. It was on the same meridian with spot 2.

Note on the First Satellite of Jupiter. By E. E. Barnard, M.A.

In reference to my previous remarks on the apparent duplicity of this satellite, I would state that it now transits in front of the dark south equatorial belt, and therefore does not appear dark in transit, being very nearly the same depth of shade as the belt when in mid-transit. Before these dark transits can again be observed the satellite's apparent latitude must increase considerably to shift it on to the bright surface of the planet south of the equatorial belt. This will not occur before the opposition of 1892.

I have been carefully watching the satellite, however, with the 12-in. when in transit as a bright spot, before it reaches the point of disappearance.

On August 3 I examined it thus, with the 36-inch refractor, when it appeared as an elongated white spot, the preceding end of which was the smaller. Under the best definition, with 700 diameters, this elongation was decidedly noticeable, and in moments of extra definition I suspected a line of separation; but this I could not be sure of. If the satellite actually consisted of two bodies the distance between their centres could scarcely have exceeded $0''{\cdot}2$.

The angle of position was estimated to be $265° \pm$ referred to the following end.

"At $13^h\ 0^m$ (Mt. H. M.T.) Satellite I. is surely much elongated—nearly parallel to the belts. Its shadow is large and round."

"$13^h\ 17^m$. There is no hesitation as to I. being elongated. Occasionally I think there are two; if so, the smaller one is preceding."

Shortly after this the satellite was lost or only faintly visible. Expecting to be able to catch it when leaving the disc, I turned to the east and observed Encke's Comet. Before the dome could be again turned to the south the satellite had just emerged. The definition then was not such as to give any information as to the form of the disc.

Satellite II. was carefully watched as it transited, preceding I. It appeared perfectly round until it wholly disappeared on the belt. *This was during the time that I. appeared elongated.*

Mount Hamilton:
1891 *August* 4.

On the Phenomena of the Transits of the First Satellite of Jupiter.

By E. E. Barnard.

The elongation of the disc of the first satellite at its transit on August 3, this year, recalls the first theory which I have previously offered in explanation of the apparent duplicity of that satellite at its transit on September 8, 1890.

On August 3 the angle of elongation was about 90° different from that of September 8, and the satellite appeared white in front of a dark belt.

The phenomena of both transits might now be quite satisfactorily explained by the assumption of a white belt on the satellite nearly parallel to the belts of *Jupiter*. To illustrate my idea I have prepared the drawing (Plate 14, fig. 5), which shows the appearance of the satellite on the two dates mentioned, side by side with the possible explanation. The left-hand figure of the upper drawing shows the satellite in double transit on the bright equatorial belt of *Jupiter*, September 8, 1890. The left-hand figure in the lower drawing shows the same object passing before the dark equatorial belt as an elongated white spot, on August 3, 1891.

In the first case, if a bright belt existed on the satellite, it would have the effect of apparently cutting it into two parts, since the belt would be lost in the bright surface of *Jupiter*. The satellite would, therefore, appear as two dusky dots, which, through irradiation, would appear small and round. The upper drawing explains this. In the second case—August 3—the satellite being seen on a dark ground, its dark surface would be lost, and only the bright belt would be seen, the result being just the reverse of the first case. The lower drawing explains this. In other words, if there is a bright belt on I., that satellite will appear double when its transit occurs over a bright part of *Jupiter*, since the dark portions of its surface alone will be visible. When it transits before a dark belt it will appear elongated, the bright belt of the satellite alone being seen.

If the drawing is examined at a distance of six or eight feet, it will clearly illustrate these statements.

Whether the above is the true explanation of the observed phenomena or not must be decided by future observations. The only other alternative is that the satellite is double. In either case the observations certainly establish an important fact. Either the satellite has a bright belt on it similar and nearly parallel to those of *Jupiter*, and, reasoning from analogy, it rotates on an axis nearly perpendicular to the plane of its orbit, or it is actually double.

The true theory can be settled with absolute certainty by careful observations. If the phenomena are caused by a white belt, the satellite, when it transits a bright portion of *Jupiter*,

should always appear double, the apparent components nearly vertical to the belts of *Jupiter*; when it transits a dark belt it should always appear elongated in a line nearly parallel to the belts of *Jupiter*. If it is actually double the elongation or line of apparent duplicity should be seen under all angles.

In reference to the other satellites I have seen nothing to indicate a belt on either of them. I am certain there is nothing of the kind on the 3rd. Though I have often noticed an irregular dark marking on this satellite, I have seen nothing to indicate a belt.

Mount Hamilton:
1891 *August* 6.

Observations of the Solar Eclipse of 1891 *June* 6, *made at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer-Royal.*)

Observations of the Beginning of the Eclipse.

	G.M.T.				Instrument.	Aperture in ins.	Power.	Observer.
1891.	d	h	m	s				
June	6	5	2	29·3	S.E. Equat.	12·8	295	A.D.
		5	2	24·0	E. Equat.	6·7	220	L.
		5	2	11·7	Altaz.	4	100	A.C.
		5	2	36·0	Simms No. 1	4	75	S.D.

No observations of the end of the Eclipse were made, the Sun being hidden by clouds at the time.

The initials A. D., L., A. C., and S. D. are those of Mr. Downing, Mr. Lewis, Mr. Crommelin, and Mr. Dolman respectively.

During the progress of the Eclipse observations were made with the South-East Equatoreal, with the object of determining corrections to the Moon's tabular R.A. and N.P.D., and to the tabular semidiameters of the Sun and Moon.

The circumstances of this Eclipse were, however, not favourable for determination of corrections to the semidiameters.

The following measures were made by Mr. Downing, the declination microscopes being read by Mr. Thackeray:—

Putting—

$d\alpha$ = correction to Moon's R.A.

$d\delta$ = correction to Moon's N.P.D.

ds = correction to Moon's semidiameter

$d\mathrm{A}$ = correction to Sun's R.A.

$d\Delta$ = correction to Sun's N.P.D.

$d\mathrm{S}$ = correction to Sun's semidiameter

(1) From $5^h\ 14^m\ 24^s$ to $5^h\ 16^m\ 49^s$ G.M.T. 2 differences of N.P.D. of p and f cusps were observed, giving

$$+\tfrac{1}{4}da + d\delta + \tfrac{5}{4}dS + \tfrac{5}{4}ds.$$

(2) From $5^h\ 19^m\ 44^s$ to $5^h\ 33^m\ 13^s$ G.M.T. 5 differences of R.A. of p and f cusps were observed, giving

$$+da + d\delta + 2dS + 2ds.$$

(3) From $5^h\ 35^m\ 6^s$ to $5^h\ 42^m\ 40^s$ G.M.T. 7 differences of N.P.D. of south limbs of Sun and Moon were observed, giving

$$-d\delta + dS - ds.$$

(4) From $6^h\ 1^m\ 35^s$ to $6^h\ 7^m\ 52^s$ G.M.T. 3 differences of R.A. of p and f cusps were observed, giving

$$-\tfrac{1}{2}da + \tfrac{3}{2}d\delta + 2dS + 2ds.$$

Four resulting equations were found by taking the sums of the constituent equations in each group, obtained by a comparison of the measured with the tabular quantity as affected by the symbolical corrections $da - d\mathrm{A}$, $d\delta - d\Delta$, ds and $d\mathrm{S}$:—

$-13''.52 =$	$+0.511\,(da - d\mathrm{A})$	$+2.271\,(d\delta - d\Delta)$	$+2.446\,ds$	$+2.478\,d\mathrm{S}$
$-31.24 =$	$+4.743$	$+6.035$	$+9.137$	$+9.267$
$+13.77 =$		-7.000	-7.000	$+7.000$
$-32.98 =$	-2.017	$+4.171$	$+5.555$	$+5.620$

the solution of which is

$$\begin{aligned} da - d\mathrm{A} &= +2''.306 \\ d\delta - d\Delta &= -5.204 \\ ds &= +1.043 \\ d\mathrm{S} &= -2.192 \end{aligned}$$

From observations of the Sun made on eight days between 1891 May 28 and June 13 :

$$d\mathrm{A} = -1''.50 \qquad d\Delta = -0''.33$$

Combining this result with that obtained from the equatorial observations during the eclipse, we obtain for the corrections to the tabular place of the Moon in R.A. and N.P.D. and to the tabular semidiameters of the Moon and Sun :—

$$\begin{aligned} da &= +0''.80 = +0^s.053 \\ d\delta &= -5.53 \\ ds &= +1.04 \\ d\mathrm{S} &= -2.19 \end{aligned}$$

From five transits of the Sun's diameter made on the afternoon of June 15, and ten measures of the diameter in N.P.D. made on the afternoon of June 17, with the same instrument and by the same observers, the apparent corrections to the tabular semidiameter of the Sun were found to be :—

$$\text{in R.A.} = -0^{s}\cdot029 = -0''\cdot40$$
$$\text{in N.P.D.} = \quad -1\cdot01$$

The telescope of the south-east equatoreal has an aperture of 12·8 inches, and a magnifying power of 295 was used.

Advantage was also taken of the circumstance that both the following vertical and lower horizontal limbs of the Moon were in turn projected on the Sun to take an altazimuth observation in the ordinary way. A correction of $-3''$ was applied to the interpolated tabular semidiameter of the Moon, and the corrections to tabular R.A. and N.P.D. of the Moon were then deduced as $-0^{s}\cdot40$ and $-5''\cdot0$.

Applying the corrections to tabular places and semidiameters indicated by the south-east equatoreal observations, a computation was made of the time of geometrical first contact, which gave $5^{h}\ 2^{m}\ 4^{s}$ G.M.T., the N.A. time being $5^{h}\ 2^{m}\cdot2$.

The weather was very unfavourable during the eclipse. Most of the observations were made through cloud, and the cusps and limbs were sometimes very faint indeed and difficult to observe.

Royal Observatory, Greenwich:
1891 *August* 7.

Observations of the Transit of Mercury, 1891 *May* 10.

By W. J. Macdonnell.

I forward a few notes on the Transit of *Mercury* as observed here with a 6-inch Equatoreal Refractor, by Grubb, of Dublin. The geographical position of Port Macquarie is South Latitude 31° 27′, East Longitude $10^{h}\ 11^{m}\ 40^{s}\cdot41$ ($6^{m}\ 49^{s}\cdot60$ East of Sydney).

May 10 was a clear, bright day, but definition was disturbed, the Sun's limb boiling and very unsteady. The times were taken from a sidereal clock in local sidereal time, and reduced to Sydney Mean Time, the clock error being found from star transits on the evening before and after the Transit of *Mercury*.

Ingress.

	h	m	s	
First Contact	9	59	30	Noted a little too late, perhaps about 20 seconds. ⊙'s limb very unsteady.
Second Contact	10	4	4	No black drop, but a hazy ligament formed; the time noted was the appearance of a light between *Mercury* and Sun.

Egress.

	h	m	s	
First Contact	2	50	16·5	Definition improved; time noted at first formation of ligament. Observation considered fair.
Last Contact	2	55	3·5	A little too soon, as both planet and Sun were unsteady.

No halo was seen round the planet, nor any light speck on its disc, although carefully searched for.

My telescope has a clear aperture of 6 inches, 97 inches focus. A Kellner eyepiece, power 70, was used for the contacts, and negative eyepieces of 110 and 200 for physical observations during the Transit. A solar diagonal and tinted wedge were used in conjunction with the eyepieces.

A few spots were observed on the Sun, forming a strong contrast with the intense blackness of *Mercury*. At intervals during the Transit the definition was good, *Mercury* bearing the power of 200 well, but no signs of an atmosphere were visible. I remember seeing a luminous halo round *Venus* during the Transit of December 1874, but nothing of the kind could be traced on this occasion.

Port Macquarie, New South Wales:
1891 *May* 14.

The Conjunction of Venus and Jupiter, 1891 April 7, observed at Windsor, New South Wales. By John Tebbutt.

Australia was well situated for the observation of the near approach of the planets *Venus* and *Jupiter* on April 7, 1891. Notwithstanding occasional clouds, I succeeded in obtaining twelve good measures of the differences of right ascension and of north polar distance with the filar micrometer of the 8-inch equatoreal. The steadiness and definition of the images were unusually satisfactory, and the individual measures very consistent. The following are the results, together with a comparison of them with those derived by interpolation with second differences from the *Nautical Almanac*. The correction for the defective illumination of *Jupiter's* western limb is insensible. The differential co-ordinates correspond to the mean of the twelve transits of *Jupiter's* centre over the single micrometer thread, which itself corresponds to $19^h\ 9^m\ 39^s{\cdot}9$ sidereal, or $18^h\ 6^m\ 27^s{\cdot}3$ mean time, at Windsor.

	h	m	s
Mean of sidereal times of transits of *Venus'* second limb ...	19	9	28·18
Sidereal time of semidiameter passing the meridian			−0·52
Concluded mean of sidereal times of transit of *Venus'* centre ...	19	9	27·66
Mean of sidereal times of transits of *Jupiter's* limbs	19	9	39·90
Difference of transits of centres. *Jupiter–Venus*			+12·24
Correction for error in perpendicularity of micrometer threads			− 0·10
Correction due to change of *Venus'* R.A.			− 0·04
Correction for differential refraction			− 0·02
Correction for differential parallax			+ 0·29
Concluded difference of geocentric apparent R.A. *Jupiter–Venus*			+12·37
Difference per *Nautical Almanac*			+12·22
Observation − Calculation ...			+ 0·15

	°	′	″
Observed difference of N.P.D. of north limb of planets... ...		+11	47·4
Correction for semidiameter of *Venus*			− 7·7
Correction for semidiameter of *Jupiter*			+16·1
Correction for change of *Venus'* N.P.D.			+ 0·2
Correction for differential refraction			+ 0·2
Correction for differential parallax			− 3·0
Concluded difference of geocentric apparent N.P.D. *Jupiter–Venus*		+11	53·2
Difference per *Nautical Almanac*		+11	54·1
Observation − Calculation ...			− 0·9

Windsor, New South Wales:
1891 *June* 1.

Ephemeris of the Satellite of Neptune, 1891–92. By A. Marth.

Greenwich, Noon.	P′	a	b	$u-U$	Diff.	U	B
1891.	°	″	″	°	°	°	°
Oct. 24	330·34	16·84	9·37	334·43	612·34	122·11	−33·81
Nov. 3	330·13	·89	9·38	226·77	·31	122·37	33·73
13	329·87	·93	9·38	119·08	·28	122·66	33·64
23	329·60	·95	9·37	11·36	·26	122·97	33·54
Dec. 3	329·32	·95	9·34	263·62	·26	123·28	33·44
13	329·05	·93	9·31	155·88	·26	123·59	33·34
23	328·80	·90	9·26	48·14	·28	123·88	33·24
1892.							
Jan. 2	328·57	16·85	9·21	300·42	612·32	124·14	−33·15
12	·38	·79	9·16	192·74	·36	·36	33·06
22	·23	·71	9·10	85·10	·41	·53	33·00
Feb. 1	328·13	·62	9·04	337·51	·46	·65	32·95
11	·08	·53	8·98	229·97	·52	·70	32·92
21	·09	·44	8·93	122·49	·59	·69	32·91
Mar. 2	328·15	·34	8·88	15·08	·65	·62	32·93
12	·26	·25	8·84	267·73	·71	·49	32·96
22	·43	·16	8·81	160·44	612·76	·30	33·01
Apr. 1	328·64	16·09	8·78	53·20		124·05	−33·07

The values of P′, a, b, and $u-U$ are to be interpolated directly for the times for which the apparent positions of the satellite are required, and the position-angles p and distances s of the satellite are then found by means of the formulæ:

$$s \sin (P'-p) = a \sin (u-U),$$
$$s \cos (P'-p) = b \cos (u-U).$$

In the May number of the *Monthly Notices*, on page 439, Mr. Isaac Roberts has communicated position-angles of the satellite, which he has deduced from measurements of eight of his photographs of *Neptune*. The strict testing of these angles would require that either a good series of micrometrical measures made during the last opposition should be available or that the changes of the elements of the orbit should be better known than they are at present (cf. the remarks on pp. 459–460 of vol. 49). But though, on account of the existing uncertainty of the shifting of the plane of the orbit, only approximate elements can be made use of, a comparison of the position-angles derived from the photographs with the corresponding computed places will not be without interest, as it sufficiently indicates the uncertainties pro-

duced by the difficulties of the measurements, which Mr. Roberts has mentioned. The following are the computed places of the satellite at the times corresponding to the beginning, middle, and ending of each exposure, as they are deduced from the elements adopted in the ephemeris published in vol. 50 :—

	Computed Dist.	Computed Posit.	Measured Posit.
1890.	″	°	° ′
Dec. 9	16·62	64·21	
	16·78	62·10	59 28
	16·88	60·02	
12	16·82	241·14	
	16·83	240·97	232 10
	16·84	240·79	
1891.			
Jan. 10	14·10	260·27	
	14·25	259·27	261 46
	14·41	258·39	
Feb. 1	13·10	26·76	
	12·86	25·21	31 29
	12·62	23·61	
1891.			
Feb. 4	12·70	204·29	
	12·56	203·32	207 6
	12·42	202·33	
10	11·51	195·77	
	11·30	194·00	193 55
	11·09	192·16	
20	12·56	267·89	
	12·81	266·18	277 3
	13·06	264·54	
24	16·00	48·03	
	15·91	47·13	44 53
	15·82	46·23	

Ephemeris for Physical Observations of the Moon. By A. Marth.

1891 Nov. 9 to Dec. 25.

Greenwich, Noon.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration. Sel. Long. of the Earth.	Geocentric Libration. Lat. of the Earth.	Geocentric Libration. Combined Amount.	Direction.
1891.	°	°	°	°	°	°
Nov. 9	7·15	+0·28	−5·30	+6·76	8·58	37·9
10	19·32	·25	4·38	6·78	8·07	32·7
11	31·48	·22	3·17	6·38	7·12	26·3
12	43·63	·19	1·73	5·57	5·83	17·2
13	55·77	·16	−0·14	4·38	4·39	1·8
14	67 91	·13	+1·49	2·90	3·26	332·8
15	80·05	+0·10	+3·04	+1·23	3·28	292·1
16	92·18	·06	4·39	−0·51	4·42	263·4
17	104·32	+ ·03	5·46	2·18	5 88	248·2
18	116·46	·00	6·19	3·67	7·19	239·2
19	128·60	− ·03	6·51	4·92	8·15	232·8
20	140·74	·06	6·45	5·86	8·73	227·6
21	152·89	·09	6·03	6·49	8·85	222·7
22	165·05	−0·12	+5·29	−6·79	8·60	217·8
23	177·21	·15	4·30	6·78	8·02	212·2

Greenwich, Noon.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration. Sel. Long. of the Earth.	Geocentric Libration. Sel. Lat. of the Earth.	Geocentric Libration. Combined Amount.	Direction.
1891.	°	°	°	°	°	°
Nov. 24	189·38	−0·18	+3·12	−6·48	7·18	205·6
25	201·55	·21	1·82	5·89	6·17	197·1
26	213·73	·23	+0·49	5·06	5·09	185·6
27	225·92	·26	−0·81	−4·01	4·09	168·7
Dec. 7	347·80	−0·51	−3·47	+6·78	7·61	26·7
8	359·96	·54	2·59	6·48	6·98	21·7
9	12·11	·56	1·60	5·79	6·00	15·4
10	24·26	·59	−0·51	4·73	4·76	6·2
11	36·40	·62	+0·61	3·38	3·43	349·8
12	48·54	·65	1·75	1·81	2·52	316·1
13	60·67	−0·68	+2·82	+0·14	2·82	272·9
14	72·80	·71	3·77	−1·52	4·07	248·0
15	84·93	·74	4·55	3·07	5·49	235·9
16	97·05	·77	5·08	4·42	6·73	228·9
17	109·18	·80	5·34	5·48	7·65	224·1
18	121·31	·82	5·27	6·23	8·15	220·1
19	133·45	·85	4·88	6·64	8·24	216·2
20	145·59	−0·87	+4·19	−6·73	7·92	211·8
21	157·73	·90	3·23	6·51	7·26	206·3
22	169·88	·92	2·05	6·00	6·34	198·8
23	182·04	·94	+0·77	5·24	5·31	188·7
24	194·20	·96	−0·58	4·26	4·30	172·3
25	206·37	−0·98	−1·89	−3·10	3·63	148·7

Ephemerides of the Satellites of Saturn, 1891–92. By A. Marth.

Though the proper determination of the plane of *Saturn's* equator as the fundamental plane to which the orbits of the satellites are to be referred may have to be postponed till the results of the observations of 1892 shall have become available, the values of the nodes and inclinations of the orbits of Tethys, Rhea, and Enceladus, which Dr. Hermann Struve has deduced from his observations made during the four oppositions of 1886–89, and of which he has given some account in his papers published in Nos. 2945–46 and 2983–84 of the *Astronomische Nachrichten*, indicate the position of the planet's equator well enough to allow some fairly approximate assumption to be made, quite independently of any observations of the ring. The values of

the node and inclination of the fundamental plane adopted in the following ephemerides are, in reference to the planes parallel to the equator and the ecliptic,

	Equator. N.	J.	Ecliptic. Node.	Inclin.	
1892·0	125°·9363	6°·9526	167°·0785	28°·0711	1°·1786
or 1891 Oct. 14	125·9278	6·9536	167·9755	28·0711	1·1789
92 Aug. 9	125·9603	6·9499	167·9870	28·0710	1·1778

The longitudes l, L, Λ of the ephemerides being referred to the equator, the angle 1°·1786 given in the last column must be subtracted, if they are to be referred to the ecliptic.

In the following tables P denotes the position-angle of the axis of *Saturn*, L+180° the planetocentric longitude of the Earth referred to the assumed fundamental plane, Λ+180° that of the Sun or Λ−L the difference between the two. B and B denote the planetocentric latitude of the Earth and Sun above the fundamental plane. The last column gives the longitude of *Saturn's* central meridian corrected for phase.

Greenwich Noon.	P	L	B	B	Λ−L	Long. of ♄ Central Merid.	Diff.
1891.	°	°	°	°	°	°	
Oct. 14	355·495	175·592	+1·217	−0·217	−2·313	39·51	1687·45
16	·515	175·799	1·321	0·186	2·459	286·96	·46
18	·535	176·003	1·424	0·155	2·602	174·42	·46
20	·554	176·205	1·526	0·124	2·743	61·88	·47
22	·573	176·405	1·626	0·093	2·882	309·35	·47
24	355·592	176·603	+1·724	−0·063	−3·018	196·82	·48
26	·611	176·798	1·821	−0·032	3·152	84·30	·48
28	·630	176·990	1·916	−0·001	3·284	331·78	·49
30	·648	177·180	2·010	+0·029	3·412	219·27	·49
Nov. 1	·666	177·367	2·102	0·060	3·538	106·76	·50
3	355·684	177·550	+2·191	+0·091	−3·660	354·26	1687·51
5	·701	177·730	2·279	0·122	3·779	241·77	·52
7	·718	177·907	2·365	0·152	3·894	129·29	·52
9	·735	178·080	2·448	0·183	4·006	16·81	·52
11	·752	178 249	2·529	0·214	4·115	264·33	·53
13	355·768	178·415	+2·608	+0·244	−4·219	151·86	·54
15	·784	178·576	2·685	0.275	4·320	39·40	·54
17	·799	178·734	2·759	0·306	4·416	286·94	·55
19	·814	178·887	2·831	0·337	4·508	174·49	·56
21	·829	178·036	2·900	0·367	4·596	62·05	·56
23	355·843	179·180	+2·967	+0·398	−4·679	309·61	1687·57
25	·857	179·320	3·031	0·429	4·758	197·18	·58

Greenwich Noon.	P	L	B	*B*	A−L	Long. of h Central Merid.	Diff.
1891.	°	°	°	°	°	°	
Nov. 27	355·870	179·455	+3·092	+0·459	-4·832	84·76	1687·58
29	·883	179·585	3·151	0·490	4·901	332·34	·59
Dec. 1	·895	179·710	3·207	0·521	4·965	219·93	·59
3	355·907	179·830	+3·260	+0·551	−5·024	107·52	·60
5	·919	179·944	3·310	0·582	5·077	355·12	·61
7	·930	180·053	3·357	0·613	5·125	242·73	·61
9	·940	180·157	3·401	0·643	5·168	130·34	·62
11	·950	180·255	3·442	0·674	5·205	17·96	·62
13	355·959	180·347	+3·480	+0·705	−5·236	265·58	1687·63
15	·968	180·433	3·515	0·735	5·262	153·21	·64
17	·976	180·514	3·546	0·766	5·282	40·85	·64
19	·983	180·589	3·575	0·797	5·295	288·49	·65
21	·990	180·658	3·600	0·827	5·303	176·14	·66
23	355·996	180·720	+3·622	+0·858	−5·305	63·80	1687·66
25	356·002	180·776	3·640	0·888	5·300	311·46	·67
27	·007	180·826	3·655	0·919	5·287	199·13	·67
29	·011	180·870	3·667	0·950	5·272	86·80	·68
31	·015	180·907	3·676	0·980	5·248	334·48	·68
1892.							
Jan. 2	356·018	180·938	+3·681	+1·011	−5·218	222·16	1687·69
4	·020	180·962	3·683	1·041	5·181	109·85	·69
6	·022	180·980	3·681	1·072	5·138	357·54	·70
8	·023	180·991	3·676	1·102	5·088	245·24	·70
10	·023	180·995	3·668	1·133	5·032	132·94	·71
12	356·023	180·993	+3·656	+1·164	−4·969	20·65	·72
14	·022	180·985	3·641	1·194	4·900	268·37	·72
16	·021	180·970	3·623	1·225	4·825	156·09	·72
18	·019	180·949	3·602	1·255	4·743	43·81	·73
20	·016	180·922	3·577	1·286	4·655	291·54	·73
22	356·013	180·888	+3·549	+1·316	−4·560	179·27	1687·73
24	·009	180·848	3·518	1·347	4·459	67·00	·74
26	356·004	180·802	3·484	1·377	4·352	314·74	·74
28	355·999	180·750	3·447	1·408	4·239	202·48	·74
30	·993	180·691	3·407	1·438	4·120	90·22	·75
Feb. 1	355·986	180·627	+3·364	+1·469	−3·995	337·97	·75
3	·979	180·557	3·319	1·499	3·864	225·72	·75
5	·972	180·482	3·271	1·530	3·728	113·47	·76
7	·964	180·401	3·220	1·560	3·586	1·23	·76

Greenwich Noon.	P	L	B	*B*	A−L	Long. of b Central Merid.	Diff.
1892.	°	°	°	°	°	°	°
Feb. 9	355·955	180·315	+3·167	+1·591	−3·440	248·99	1687·76
11	355·946	180·224	+3·111	+1·621	−3·288	136·75	1687·76
13	·936	180·128	3·053	1·652	3·132	24·51	·76
15	·926	180·028	2·993	1·682	2·971	272·27	·76
17	·916	179·924	2·931	1·713	2·805	160·03	·76
19	·905	179·815	2·867	1·743	2·636	47·79	·77
21	355·894	179 702	+2·801	+1·774	−2·462	295·56	·76
23	·882	179·585	2·734	1·804	2·284	183·32	·76
25	·870	179·465	2·665	1·834	2·103	71·08	·76
27	·858	179·341	2·595	1·865	1·919	318·84	·76
29	·845	179·215	2·524	1·895	1·732	206·60	1687·76
Mar. 2	388·832	179·086	+2·451	+1·926	−1·543	94·36	

The daily rate of rotation adopted in the computation of the Central Meridian is 843°·80, corresponding to a period of $10^h\ 14^m{\cdot}364$. It approximately represents the motion of the spots observed by Mr. A. Stanley Williams, the account of which is published in No. 3051 of the *Astron. Nachrichten.*

The values referring to the ball and ring depend on Bessel's old determinations. In the tables for the five inner satellites, a and b denote the semiaxes of the apparent orbits, l—L the orbital longitudes of the satellites reckoned from the points which are in superior conjunction with the planet's centre or in opposition to the Earth in longitude. By adding to l—L the value of L from the preceding table, the longitudes l are found, which are corrected for the equation of light.

Greenwich Noon.	Semidiameter of Ball. Equat.	Phase.	Polar.	Semiaxis of Ring. Major.	Minor.	*Mimas.* a_1	b_1	l_1 − L	Diff.
189v.	″	″	″	″	″	″	″	°	°
Oct. 14	7·90	0·006	7·12	18·20	0·39	24·88	+0·53	125·42	763·83
16	7·91	·007	7·13	18·23	0·42	24·91	0·58	169·25	·84
18	7·92	·008	7·15	18·26	0·45	24·95	0·62	213·09	·84
20	7·93	·009	7·16	18 29	0·49	24·99	0·67	256·93	·84
22	7·95	·010	7·17	18·32	0·52	25·04	0·71	300·77	·85
24	7·96	·011	7·18	18·36	0·55	25·08	+0·76	344·62	·85
26	7·98	·012	7·20	18·39	0·58	25·13	0·80	28·47	·86
28	7·99	·013	7·21	18·43	0·62	25·18	0·85	72·33	·86
30	8·01	·014	7·23	18·47	0·65	25·23	0·89	116·19	·86
Nov. 1	8·03	·015	7·24	18·51	0·68	25·29	0·93	160·05	·87
3	8·05	·016	7·26	18·55	0·71	25·35	+0·97	203·92	763·88
5	8·07	·018	7·28	18·59	0·74	25·41	1·01	247·80	·88

Greenwich Noon.	Semidiameter of Ball. Equat.	Phase.	Polar.	Semiaxis of Ring. Major.	Minor.	*Mimas.* a_1	b_1	l_1-L	Diff.
1891.	″	″	″	″	″	″	″	°	°
Nov. 7	8·09	0·019	7·29	18·64	0·77	25·47	+1·05	291·68	763·89
9	8·11	·020	7·31	18·68	0·80	25·53	1·09	335·57	·89
11	8·13	·021	7·33	18·73	0 83	25·60	1·13	19·46	·90
13	8·15	·022	7·35	18·78	0·86	25·66	+1·17	63·36	·90
15	8·17	·023	7·37	18·83	0·88	25·73	1·21	107·26	·91
17	8·19	·024	7·39	18·88	0·91	25·80	1·24	151·17	·91
19	8·21	·025	7·41	18·94	0·94	25·88	1·28	195·08	·92
21	8·24	·026	7·43	18·99	0·96	25·95	1·32	239·00	·92
23	8·26	·027	7·46	19·05	0·99	26·03	+1·35	282·92	763·93
25	8·29	·028	7·48	19·11	1·01	26·11	1·38	326·85	·93
27	8·31	·029	7·50	19·17	1·03	26·19	1·41	10·78	·94
29	8·34	·030	7·52	19·23	1·06	26·27	1·44	54·72	·95
Dec. 1	8·37	·031	7·55	19·29	1·08	26·36	1·47	98·67	·96
3	8·39	·032	7·57	19·35	1·10	26·44	+1·50	142·63	·96
5	8·42	·033	7·60	19·41	1·12	26·53	1·53	186·59	·96
7	8·45	·034	7·62	19·48	1·14	26·62	1·56	230·55	·97
9	8·48	·034	7·65	19·54	1·16	26·71	1·58	274·52	·98
11	8·51	·035	7·68	19·61	1·18	26·80	1·61	318·50	·98
13	8·54	·036	7·70	19·68	1·19	26·89	+1·63	2·48	763·99
15	8·57	·036	7·73	19·75	1·21	26·98	1·65	46·47	764·00
17	8·60	·037	7·76	19·81	1·23	27·08	1·67	90·47	·00
19	8·63	·037	7·78	19·88	1·24	27·17	1·69	134·47	·01
21	8·66	·037	7·81	19·95	1·25	27·27	1·71	178·48	·02
23	8·69	·037	7·84	20·02	1·26	27·36	+1·73	222·50	·02
25	8·72	·037	7·87	20·10	1·27	27·46	1·74	266·52	·03
27	8·75	·037	7·89	20·17	1·28	27·56	1·76	310·55	·03
29	8·78	·037	7·92	20·24	1·29	27·66	1·77	324·58	·04
31	8·81	·037	7·95	20·31	1·30	27·76	1·78	38·62	·04
1892.									
Jan. 2	8·84	0·037	7·98	20·38	1·31	27·85	+1·79	82·66	764·05
4	8·87	·036	8·01	20·45	1·31	27·95	1·80	126·71	·06
6	8·90	·036	8·04	20·53	1·32	28·05	1·80	170·77	·06
8	8·94	·035	8·06	20·60	1·32	28·15	1·80	214·83	·07
10	8·97	·035	8·09	20·67	1·32	28·25	1·81	258·90	·08
12	9·00	·034	8·12	20·74	1·32	28·35	+1·81	302·98	·08
14	9·03	·033	8·15	20·81	1·32	28·44	1·81	347·06	·08
16	9·06	·032	8·17	20·88	1·32	28·54	1·80	31·14	·09
18	9·09	·031	8·20	20·95	1·32	28·63	1·80	75·23	·10

Greenwich Noon.	Semidiameter of Ball. Equat.	Phase.	Polar.	Semiaxis of Ring. Major.	Minor.	*Mimas.* a_1	b_1	l_1-L	Diff.
1892.	″	″	″	″	″	″	″	°	°
Jan. 20	9·12	0·030	8·23	21·02	1·31	28·72	+1·79	119·33	764·10
22	9·15	·029	8·25	21·09	1·31	28·81	+1·78	163·43	764·10
24	9·18	·028	8·28	21·15	1·30	28·90	1·77	207·53	·11
26	9·20	·027	8·31	21·22	1·29	28·99	1·76	251·64	·12
28	9·23	·025	8·33	21·28	1·28	29·08	1·75	295·76	·12
30	9·26	·024	8·35	21·34	1·27	29·16	1·73	339·88	·12
Feb. 1	9·29	·023	8·38	21·40	1·26	29·25	+1·72	24·00	·13
3	9·31	·021	8·40	21·46	1·24	29·33	1·70	68·13	·13
5	9·34	·020	8·42	21·52	1·23	29·41	1·68	112·26	·13
7	9·36	·018	8·44	21·57	1·21	29·48	1·66	156·39	·14
9	9·38	·017	8·46	21·63	1·20	29·55	1·63	200·53	·14
11	9·40	·015	8·48	21·68	1·18	29·62	+1·61	244·67	764·14
13	9·42	·014	8·50	21·73	1·16	29·69	1·58	288·81	·15
15	9·44	·013	8·52	21·77	1·14	29·75	1·55	332·96	·15
17	9·46	·011	8·54	21·82	1·12	29·81	1·52	17·11	·15
19	9·48	·010	8·56	21·86	1·09	29·87	1·49	61·26	·15
21	9·50	·009	8·57	21·90	1·07	29·92	+1·46	105·41	·15
23	9·51	·008	8·58	21·93	1·05	29·97	1·43	149·56	·15
25	9·53	·007	8·60	21·97	1·02	30·02	1·40	193·71	·15
27	9·54	·005	8·61	22·00	1·00	30·06	1·36	237·86	·16
29	9·55	·004	8·62	22·02	0·97	30·10	1·33	282·02	764·15
Mar. 2	9·56	0·003	8·63	22·05	0·94	30·13	+1·29	326·17	

Greenwich Noon.	*Enceladus.* a_2	b_2	l_2-L	Diff.	*Tethys.* a_3	b_3	l_3-L	Diff.
1891.	″	″	°	°	″	″	°	°
Oct. 14	31·91	+0·68	202·32	525·28	39·50	+0·84	119·289	381·205
16	31·96	0·74	7·60	·28	39·56	0·91	120·494	·208
18	32·01	0·80	172·88	·29	39·62	0·99	161·702	·212
20	32·06	0·86	338·17	·29	39·69	1·06	182·914	·215
22	32·12	0·91	143·46	·29	39·76	1·13	204·129	·218
24	32·18	+0·97	308·75	·30	39·83	+1·20	225·347	·221
26	32·24	1·02	114·05	·30	39·91	1·27	246·568	·225
28	32·30	1·08	279·35	·31	39·99	1·34	267·793	·229
30	32·37	1·14	84·66	·31	40·07	1·41	289·022	·233
Nov. 1	32·44	1·19	249·97	·32	40·16	1·47	310·255	·237
3	32·52	+1·24	55·29	525·32	40·25	+1·54	331·492	381·241
5	32·59	1·30	220·61	·32	40·34	1·60	352·733	·245
7	32·67	1·35	25·93	·33	40·44	1·67	13·978	·250

Greenwich Noon.	*Enceladus.* a_2	b_2	l_2-L	Diff.	*Tethys.* a_2	b_2	l_2-L	Diff.
1891.	″	″	°	°	″	″	°	°
Nov. 9	32·75	+1·40	291·26	525·33	40·54	+1·73	35·228	381·254
11	32·84	1·45	356·59	·34	40·65	1·79	56·482	·258
13	32·92	+1·50	161·93	·34	40·76	+1·85	77·740	·263
15	33·01	1·55	327·27	·35	40·87	1·91	99·003	·268
17	33·10	1·60	132·62	·35	40·98	1·97	120·271	·273
19	33·20	1·64	297·97	·36	41·10	2·03	141·544	·278
21	33·29	1·69	103·33	·36	41·22	2·09	162·822	·283
23	33·39	+1·73	268·69	525·37	41·34	+2·14	184·105	381·288
25	33·49	1·77	74·06	·38	41·46	2·19	205·393	·293
27	33·60	1·81	239·44	·38	41·59	2·24	226·686	·299
29	33·70	1·85	44·82	·39	41·72	2·29	247·985	·304
Dec. 1	33·81	1·89	210·21	·39	41·85	2·34	269·289	·310
3	33·92	+1·93	15·60	·39	41·99	+2·39	290·599	·315
5	34·03	1·97	180·99	·41	42·13	2·43	311·914	·321
7	34·14	2·00	346·40	·41	42·27	2·48	333·235	·328
9	34·26	2·03	151·81	·41	42·41	2·52	354·563	·333
11	34·38	2·06	317·22	·42	42·55	2·56	15·896	·338
13	34·50	+2·09	122·64	525·43	42·70	+2·59	37·234	381·345
15	34·62	2·12	288·07	·43	42·85	2·63	58·579	·351
17	34·74	2·15	93·50	·44	43·00	2·66	79·930	·357
19	34·86	2·18	258·94	·45	43·15	2·69	101·287	·362
21	34·98	2·20	64·39	·45	43·30	2·72	122·649	·369
23	35·10	+2·22	229·84	·46	43·45	+2·75	144·018	·376
25	35·23	2·24	35·30	·46	43·61	2·77	165·394	·381
27	35·35	2·26	200·76	·47	43·76	2·79	186·775	·388
29	35·48	2·27	6·23	·48	43·92	2·81	208·163	·394
31	35·61	2·28	171·71	·48	44·08	2·83	229·557	·400
1892.								
Jan. 2	35·73	+2·29	337·19	525·49	44·23	+2·84	250·957	381·406
4	35·86	2·30	142·68	·49	44·39	2·85	272·363	·413
6	35·98	2·31	308·17	·50	44·54	2·86	293·776	·419
8	36·11	2·31	113·67	·51	44·70	2·87	315·195	·425
10	36·24	2·32	279·18	·51	44·86	2·87	336·620	·431
12	36·36	+2·32	84·69	·52	45·01	+2·87	358·051	·437
14	36·48	2·32	250·21	·52	45·16	2·87	19·488	·443
16	36·61	2·31	55·73	·53	45·31	2 86	40·931	·449
18	36·73	2·31	221·26	·54	45·46	2·86	62·380	·454
20	36·85	2·30	26·80	·54	45·61	2·85	83·834	·460

Enceladus.

Greenwich Noon. 1892.	a_2	b_2	l_2-L	Diff.
	″	″	°	°
Jan. 22	36·96	+2·29	192·34	525·55
24	37·08	2·28	357·89	·55
26	37·19	2·26	163·44	·55
28	37·30	2·24	328·99	·56
30	37·41	2·22	134·55	·57
Feb. 1	37·52	+2·20	300·12	·57
3	37·62	2·18	105·69	·57
5	37·72	2·15	271·26	·58
7	37·82	2·12	76·84	·58
9	37·91	2·09	242·42	·59
11	38·00	+2·06	48·01	525·59
13	38·09	2·03	213·60	·59
15	38·17	1·99	19·19	·59
17	38·25	1·96	184·78	·60
19	38·32	1·92	350·38	·60
21	38·39	+1·88	155·98	·61
23	38·45	1·83	321·59	·60
25	38·51	1·79	127·19	·60
27	38·56	1·75	292·79	·61
29	38·61	1·70	98·40	525·61
Mar. 2	38·65	+1·65	264·01	

Tethys.

a_2	b_2	l_2-L	Diff.
″	″	°	°
45·76	+2·83	105·294	381·466
45·90	2·82	126·760	·471
46·04	2·80	148·231	·476
46·18	2·78	169·707	·482
46·31	2·75	191·189	·487
46·44	+2·73	212·676	·491
46·57	2·70	234·167	·496
46·70	2·67	255·663	·501
46·82	2·63	277·164	·504
46·93	2·59	298·668	·508
47·04	+2·55	320·176	381·512
47·15	2·51	341·688	·516
47·25	2·47	3·204	·519
47·34	2·42	24·723	·522
47·43	2·37	46·245	·525
47·52	+2·32	67·770	·527
47·60	2·27	89·297	·530
47·67	2·22	110·827	·531
47·74	2·16	132·358	·533
47·80	2·11	153·891	381·534
47·85	+2·05	175·425	

Dione.

Greenwich Noon. 1891.	a_4	b_4	l_4-L	Diff.
	″	″	°	°
Oct. 14	50·60	+1·07	324·467	262·875
16	50·67	1·17	227·342	·878
18	50·75	1·26	130·220	·880
20	50·83	1·35	33·100	·884
22	50·92	1·44	295·984	·886
24	51·02	+1·53	198·870	·890
26	51·12	1·62	101·760	·893
28	51·22	1·71	4·653	·896
30	51·33	1·80	267·549	·900
Nov. 1	51·44	1·89	170·449	·904
3	51·55	+1·97	73·353	262·908
5	51·67	2·05	336·261	·911
7	51·80	2·14	239·172	·916

Rhea.

a_5	b_5	l_5-L	Diff.
″	″	°	°
70·66	+1·50	251·945	159·181
70·76	1·63	51·126	·183
70·87	1·76	210·309	·186
70·99	1·89	9·495	·188
71·12	2·02	168·683	·191
71·25	+2·15	327·874	·194
71·38	2·27	127·068	·197
71·53	2·39	286·265	·200
71·68	2·51	85·465	·204
71·83	2·63	244·669	·208
71·99	+2·75	43·877	159·211
72·16	2·87	203·088	·214
72·34	2·98	2·302	·219

Greenwich Noon.	*Dione.* a_4	b_4	l_4-L	Diff.	*Rhea.* a_5	b_5	l_5-L	Diff.
1891.	″	″	°	°	″	″	°	°
Nov. 9	51·93	+2·22	142·088	262·920	72·52	+3·10	161·521	159·222
11	52·06	2·30	45 008	·924	72·70	3·21	320·743	·227
13	52·20	+2·38	307·932	·929	72·89	+3·32	119·970	·231
15	52·34	2·45	210·861	·934	73·09	3·42	279·201	·236
17	52·49	2·53	113·795	·938	73·29	3·53	78·437	·240
19	52·64	2·60	16·733	·943	73·50	3·63	237·677	·244
21	52·79	2·67	279·676	·947	73·72	3·73	36·921	·249
23	52·94	+2·74	182·623	262·953	73·94	+3·83	196·170	159·254
25	53·10	2·81	85·576	·958	74·16	3·92	355·424	·259
27	53·27	2·87	348·534	·963	74·39	4·01	154·683	·265
29	53·44	2·94	251·497	·968	74·62	4·10	313·948	·269
Dec. 1	53·61	3·00	154·465	·974	74·86	4·19	113·217	·275
3	53·78	+3·06	57·439	·980	75·10	+4·27	272·492	·280
5	53·96	3·12	320·419	·985	75·35	4·35	71·772	·286
7	54·14	3·17	223·404	·991	75·60	4·43	231·058	·292
9	54·32	3·22	126·395	262·996	75·85	4·50	30 350	·297
11	54·50	3·27	29·391	263·003	76·11	4·57	189·647	·303
13	54·69	+3·32	292·394	·008	76·37	+4·64	348·950	159·308
15	54·88	3·36	195·402	·014	76·64	4·70	148·258	·313
17	55·07	3·40	98·416	·020	76·91	4·76	307·573	·320
19	55·26	3·44	1·436	·027	77·18	4·81	106·893	·327
21	55·46	3·48	264·463	·033	77·55	4·86	266·220	·333
23	55·65	+3·51	167·496	·038	77·72	+4·91	65·553	·339
25	55·85	3·54	70·534	·045	78·00	4·95	224·892	·346
27	56·05	3·57	333·579	·051	78·27	4·99	24·238	·352
29	56·25	3·60	236·630	·058	78·55	5·02	183·590	·358
31	56·45	3·62	139·688	·064	78·83	5·05	342·948	·364
1892.								
Jan. 2	56·65	+3·64	42·752	263·070	79·11	+5·08	142·312	159·371
4	56·85	3·65	305·822	·077	79·39	5·10	301·683	·377
6	57·05	3·66	208·899	·083	79·67	5·12	101·060	·384
8	57·25	3·67	111·982	·089	79 95	5·12	260·444	·390
10	57·45	3·68	15·071	·095	80·23	5·13	59·834	·396
12	57·65	+3·68	278·166	·102	80·81	+5·13	219·230	·403
14	57·84	3·67	181·268	·107	80·78	5·13	18·633	·409
16	58·04	3·67	84·375	·113	81·05	5·12	178·042	·414
18	58·23	3·66	347·488	·120	81·31	5·11	337·456	·421
20	58·42	3·65	250·608	·125	81·58	5·09	136·877	·427

Greenwich Noon. 1892.	*Dione.* a_s	b_s	l_s-L	Diff.	*Rhea.* a_s	b_s	l_s-L	Diff.
	″	″	°	°	″	″	°	°
Jan. 22	58·60	+3·63	153·733	263·131	81·84	+5·07	296·304	159·433
24	58·79	3·61	57·864	·137	82·10	5·04	95·737	·439
26	58·97	3·58	320·001	·142	82·35	5·00	255·176	·445
28	59·15	3·56	223·143	·148	82·60	4·96	54·621	·450
30	59·32	3·53	126·291	·153	82·84	4·92	214·071	·456
Feb. 1	59·49	+3·49	29·444	·158	83·07	+4·87	13·527	·461
3	59·65	3·45	292·602	·163	83·30	4·82	172·988	·466
5	59·81	3·41	195·765	·167	83·52	4·76	332·454	·471
7	59·96	3·37	98·932	·172	83·74	4·70	131·925	·476
9	60·11	3·32	2·104	·176	83·94	4·64	291·401	·480
11	60·25	+3·27	265·280	263·180	84·14	+4·57	90·881	159·485
13	60·39	3·22	168·460	·185	84·33	4·49	250·366	·489
15	60·52	3·16	71·645	·188	84·51	4·41	49·855	·493
17	60·64	3·10	335·833	·191	84·68	4·33	209·348	·497
19	60·75	3·04	238·024	·194	84·84	4·24	8·845	·500
21	60·86	+2·98	141·218	·197	84·99	+4·15	168·345	·503
23	60·96	2·91	44·415	·200	85·13	4·06	327·848	·506
25	61·05	2·84	307·615	·203	85·26	3·97	127·354	·509
27	61·14	2·77	210·818	·204	85·38	3·87	286·863	·512
29	61·21	2·70	114·022	263·206	85·48	3·77	86·375	159·513
Mar. 2	61·28	+2·62	17·228		85·58	+3·66	245·888	

The following are the approximate Greenwich times when the shadow of *Titan* crosses the central meridian, and when the satellite enters the shadow-cone of the planet. The times of some of the eclipses and shadow-transits of *Rhea* are also given, and it is very desirable that the latter should be carefully looked after, to ascertain whether the shadow cannot be discerned.

1891.	Gr. M. T.		1891.	Gr. M. T.	
Oct. 19	18·1	Tit. Shadow	Nov. 28	19·9	Tit. Ecl.
27	21·5	Tit. Ecl. Disapp.	Dec. 1	18·8	Rh. Sh.?
Nov. 4	16·0	Rhea Sh.?	3	22·9	Rh. Ecl.
—	17·3	Tit. Sh.	6	15·8	Tit. Sh.
6	20·2	Rh. Ecl.	10	19·7	Rh. Sh.?
12	20·7	Tit. Ecl.	12	23·8	Rh. Ecl.
13	17·0	Rh. Sh.?	14	19·1	Tit. Ecl.
15	21·1	Rh. Ecl.	19	20·6	Rh. Sh.?
20	16·6	Tit. Sh.	22	0·7	Rh. Ecl.
22	17·9	Rh. Sh.?	—	15·0	Tit. Sh.
24	22·0	Rh. Ecl.			

(*To be continued.*)

Col. Cooper's Observatory,
Markree, Collooney, Ireland.

Correction.

The values in the column "Corr. of log. Δ" in the Ephemeris for physical observations of *Jupiter*, p. 360 ff., are, owing to a mistake in transcribing the formula, considerably too large. The values should have been, at the beginning of June −34, and at the end of November and beginning of December +43, and as these values do not affect the apparent distance of the fourth satellite by more than 0″·006, the correction may be neglected. The heading β should have been B, and on p. 369, l. 13 and 14, 10^h should have been 9^h.

Erratum. By Harold Jacoby.

I desire to call attention to an error in my paper "On the Correction of Micrometric Measures for Refraction" (*Monthly Notices*, li. 2, p. 79). In the expression for $r-r'$ I should have used $(\zeta-\zeta')^3$, not $(\zeta-\zeta')^2$. The effect of this upon the result will be very small; and in the tables issued at the Royal Observatory, Cape Town, it may be entirely corrected by multiplying every number in Table I. β by $\frac{\cos(\pi-q)}{7\cdot2}$, and afterwards multiplying the quantity taken from the table by σ^3, not σ^2. The correction $\beta\sigma^3$ will then always be positive.

Columbia College, New York:
1891 *August* 6.

Errata in Mr. Christie's paper, On a New Dome to be erected at the Royal Observatory, Greenwich, vol. li., *no.* 7.

Page 436, line 18, *for* diameter *read* radius.
„ „ 20, *for* 13 feet 3 inches *read* 17 feet 3 inches.

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OF THE

ROYAL ASTRONOMICAL SOCIETY.

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*** Fellows of the Society are informed that post-cards containing the titles of papers to be read at the evening meetings will be sent to those who shall express their wish to receive them. Fellows desiring to receive the post-cards are requested to send their names to the Assistant-Secretary.

In order to enable the Secretaries to prepare complete lists in time for the issue of the post-cards, authors are particularly requested to send in their papers not later than the Tuesday preceding the day of meeting.

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The present number of the *Monthly Notices* being the last of Vol. LI., Subscribers (not Fellows) are requested to take notice that the subscription for Vol. LII., 10*s*., including postage to countries within the Postal Union, has now become due; and it is also requested that it may be forwarded to the Assistant-Secretary, Mr. W. H. WESLEY, Burlington House, London, W., on or before December 2 next; otherwise it will be considered that the subscription has not been renewed.

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